Handbook of the PETROLEUM INDUSTRY

Handbook

of the

Petroleum Industry

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by

S. S. Amdursky, M. E.
Member Rochester Engineering Society, Society American Military Engineers

In collaboration with
L. G. Marsh, A. B., and E. N. Hurlburt

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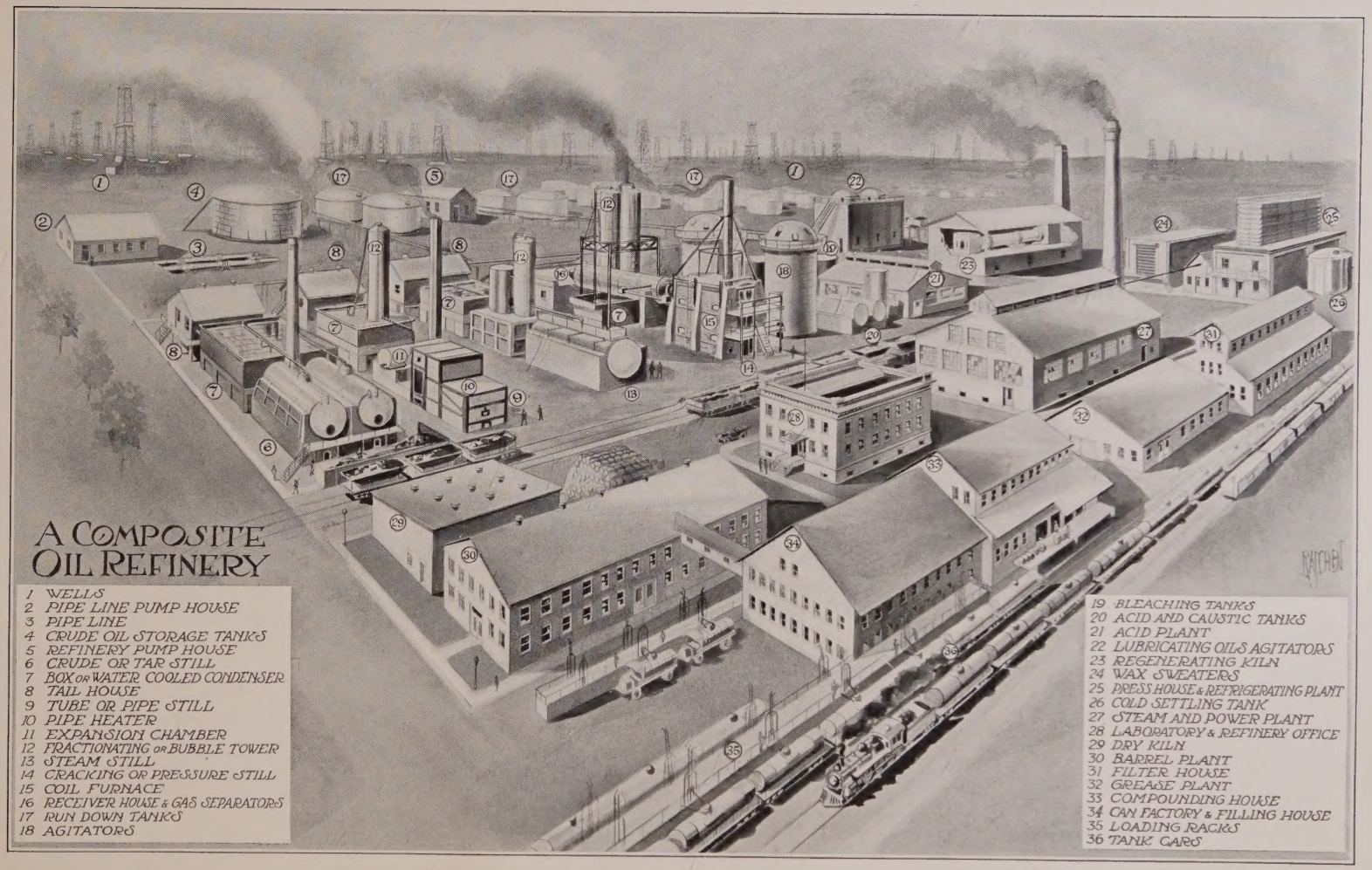

Fig. 1

The above drawing indicates the units that go to make up a complete oil refinery

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Foreword

This book, being a treatise on the Petroleum Industry and the application of instruments in operating processes connected therewith, is divided into three parts.

Part 1 (*pages 2 to 82 inclusive*) deals with:

(*a*) The production of crude petroleum (*pages 4 to 19 inclusive*).

(*b*) The refining of crude petroleum (*pages 20 to 65 inclusive*).

(*c*) The manufacture of natural-gas gasoline (*pages 66 to 80 inclusive*).

Under each division is given a limited descriptive outline of various processes, with a corresponding reference to specific points for the application of instruments in all processes where instruments are necessary to insure uniformity of quality and economy of production. This involves particularly the instruments designed for the measurement or control of temperatures and pressures, as there is hardly a process in the manufacture of petroleum products that does not call for careful consideration and control of temperature or pressure conditions.

For the purpose of continuity of treatment and convenience of reference, the pages of Part 1 are set in two columns, the material in light-face type comprising the descriptive matter, the material in dark-face type being devoted to the corresponding instrument applications. In the latter the type of instrument in each case is listed and an accompanying reference is made to the figure and page where the instrument is illustrated.

It is evident that in refinery operations the question of automatic temperature or pressure control is in many cases an individual problem and can be worked out only through a detailed and thorough understanding and correlation of conditions peculiar to each process. The competent and experienced instrument manufacturer solicits in confidence your inquiries and problems on temperature or pressure control. From long experience in applying instruments for indicating, recording and controlling temperatures and pressures in all industries, he is qualified to make the best recommendations and devise the most efficient system of automatic regulation for any process which will lend itself to such control.

Part 2 (*pages 83 to 100 inclusive*) gives in a general way the more common routine laboratory practices or tests applied to crude petroleum and its different refined products, without attempting to go into detail concerning the particular method of testing or analysis; and a short treatise on some of the instruments used in laboratory practice.

Part 3 (*pages 101 to 185 inclusive*) is a collection of tables intended to give those connected with the testing and refining of petroleum products complete and authoritative information connected with the use of instruments.

In the preparation and assembly of the descriptive part of this book, free use has been made of the various publications of the United States Bureau of Mines, and of various reference books on the producing, refining and testing of crude petroleum and its products, among the latter being Lahee's "Field Geology", Leslie's "Motor Fuels", Bell's "American Petroleum Refining", Day's "Handbook of the Petroleum Industry", and Oberfell and Alden's "Natural Gasoline". The assistance from these various sources is gratefully acknowledged.

—*The Editors*—

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Part 1

(*For Index, see pages 187 to 189 inclusive*)

(a) The production of crude petroleum (*pages 4 to 19 inclusive*).

(b) The refining of crude petroleum (*pages 20 to 65 inclusive*).

(c) The manufacture of natural-gas gasoline (*pages 66 to 80 inclusive*).

Introduction to Part 1

The birth of the petroleum industry was heralded by the early discovery that burning oil or kerosine could be distilled from the so-called rock oil found in different parts of the country as seepages or oily accumulations on the surface of springs and ponds. It was not until the discovery of the first oil well in about 1860 that a sufficient source of raw petroleum was opened up and the possibilities for commercial development realized. The real advent of the industry may be dated from that period. In the early stages of development, operating methods were naturally crude and the need for the refined products quite limited. The gasolines, naphthas and heavy residues obtained in the production of kerosine were considered in the light of necessary evils and were consequently wastefully disposed of in a manner most convenient and least expensive to the operator. This condition, however, was not destined long to exist. The advent of the motor car and the ever-increasing complexities of modern industrial life served to open broader and hitherto unknown fields for the various products formerly considered useless, and today the widespread use of motor fuels, petroleum lubricants, paraffin wax and allied products has placed the petroleum industry in a position of world preeminence.

The remarkable growth and development of the petroleum industry has made of it in reality a combination of industries. If there were some magic way of divorcing the manufacture of gasoline, kerosine, lubricating oils, paraffin wax, etc., from the refining industry, they could be regarded in the light of separate and distinct industries, involving the employment of thousands of men, enormous investment of capital and the production daily of millions of dollars worth of finished products. The extent and magnitude of the industry as a whole can be realized better by a review of refinery statistics for the past few years, as compiled by the U. S. Bureau of Mines and shown in the following table:

(Figures in units of a thousand—all in barrels of 42 U. S. gallons, except wax, coke, and asphalt)

	1922	1923	1924	1925	1926
Gasoline	147,672	179,903	213,326	259,601	299,734
Kerosine	54,913	55,927	60,026	59,689	61,768
Gas and Fuel Oils	254,910	287,481	320,476	364,991	365,195
Lubricants	23,304	26,128	27,498	21,055	32,293
Wax (lbs.)	462,003	466,647	516,491	590,577	645,790
Coke (tons)	707.1	672.5	761.1	991.0	995.3
Asphalt (tons)	1,895.3	2,327.1	2,545.6	2,677.4	2,922.8
Other finished products	4,527	5,086	8,252	8,044	8,030

For several years just prior to 1920 the consumption of refined products exceeded the production of crude petroleum. This was especially so during the war, and during the great industrial boom immediately following. The resulting high prices of crude stimulated exploration efforts, with the consequent discovery of new fields, and as a result the available supply in the industry has more than kept pace with demand and consumption.

This, however, has not been entirely as a result of increased production. The need of conservation in the refining as well as in the production of petroleum became apparent as efforts to promote greater efficiency in the utilization of crude petroleum were extended. This has resulted in readjustment and development in the petroleum and related industries, and even in others, such as the automotive industry. For example, the past few years have witnessed the development of the natural-gas-gasoline industry, the application of the cracking process, and the blending of coal-tar products with gasoline. As the demand for gasoline and other petroleum products is ever increasing and as

Introduction to Part 1—Continued

our mineral reserves underground are limited the need for most efficient and conservative methods both in production and refining of petroleum are further emphasized. It may be said truthfully however, that today the refining industry has reached a point of efficiency where no product goes to waste. Every component fraction of the crude is utilized, from the gasoline down to coke. Present improvements have resulted not so much in prevention of waste as in the converting of materials of more limited usage into other products of more desirable characteristics. This is evident in the "cracking" of the heavier oils to gasoline. The increased production of lubricants has been greatly aided also by new and improved methods of handling the heavier distillates from the crude.

The position of the individual refiner in the oil industry today is in large measure determined by the relative extent and modernization of his operating methods and his readiness to adopt new processes and policies where these react to a proven advantage. In the early days fundamental processes could easily be operated with profit. As the industry expanded, individual improvements gave different operators distinct advantages, enabling them to operate possibly at lower cost, with correspondingly greater profits. Increased competition changed this factor from an advantage to a necessity. The life and prosperity of the refiner today, both in times of plenty and during periods of depression, make necessary the strictest economy and highest efficiency in all methods and practices.

It is the purpose of this book to show where in the existing procedures of handling and refining petroleum greater accuracy with corresponding efficiency may be maintained by co-ordinated and scientific methods of measurement and control.

Fig. 2
Recording Thermometers on Gas-Fired Crude-Oil Stills

The Production of Crude Petroleum

Occurrence of Petroleum

From extensive studies and experience it has been found that the occurrence of petroleum is based in general on certain well-defined and established scientific facts and principles. These may be resolved first of all into the necessity for a granular or sandy strata of sufficient porosity to hold the accumulated oil or gas. Formations of this sort are in evidence principally in sandstone, which characterizes most of the mid-continent fields, and to a lesser extent in the limestone formations of Ohio and Indiana and shale in parts of Colorado and California. The part of the strata in which the oil occurs is termed a reservoir. An all-important requirement for a reservoir is an impervious cover or retaining roof, for without this the light petroleum constituents will escape, the lighter oils becoming volatilized and the heavier residues being left behind. This factor accounts no doubt for some of the heavy asphaltic deposits found in certain sections of the country today.

Fig. 3
Surveying-and-Sight Compass

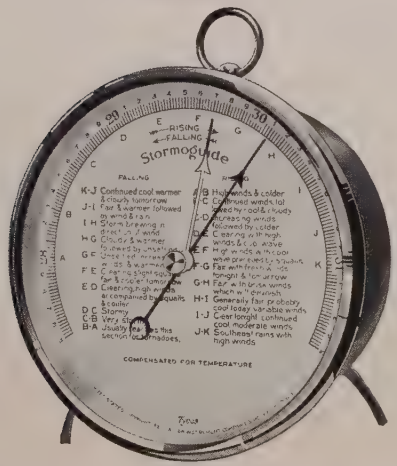


Fig. 4
Weather-Forecasting Aneroid Barometer (Indicating Type)

Instruments Applicable to Surveys for Petroleum

Geologic surveys and mappings, inso-far as they involve approximate work, reconnoissance and preliminary surveyings, may be based on the use of technical and specialized instruments, including the compass, compass-and-clinometer, hand level, and barometer.

Compasses are used for determining direction; clinometers for measuring vertical angles of slope and dip. Surveying Compasses as shown (*Fig. 3, page 4*) are especially applicable in the different phases of geologic field-work, both from the standpoint of accuracy and the fact that they are characterized by a sturdiness of construction which makes them resistant to the rough usage incidental to this class of work. In compass and clinometer surveys the Clinometer Compass (*Fig. 5, page 5*) is so constructed that it can be used either as a clinometer or as a sight compass, the sights being made in the form of a bridge which turns at right angles on its pivots.

The hand level is used for determining differences in elevation. It may be employed also in regions where the strata have dips too low to be measured by the clinometer, the dip in this case being designated as a fall of so many feet per mile.

The Locke Level is recognized by many of the leading geologists and surveyors as one of the most satisfactory instruments for hand-level survey work. The Pocket Reflecting Prism Levels (*Figs. 9 and 10, page 7*) are Locke Levels of the most approved type and are widely known for the workmanship and material that enter into their construction.

The Abney's Level (*Fig. 6, page 5*) also is extensively used in geologic surveys. This instrument possesses characteristics which enable it to be employed like the Locke and is adaptable also for use as a clinometer. The Abney's Level in the improved form is provided with a circular base on which the instrument rotates, by which means horizontal angles can be measured.

Next in importance to the nature and character of the containing rock is the slope, or lateral extent, of the reservoir. This condition embodies that geologic structure wherein the oil once formed can be separated from the gas and water which might occur simultaneously, and concentrated in one locality. Much of the crude petroleum production today comes from structures of this sort. This is evidenced in the so-called anticlinal, synclinal, and dome-shaped fields. Here one would expect to find the gas, which is of lightest density nearest the crest of the dome, water furthest down, and oil between.

Crude has been found in localities unfavorable from a geological standpoint and actually condemned by geologists. Instances of this sort are rather isolated, however, and may rightfully be considered exceptional. The importance of geology in its relation to the occurrence of petroleum has been amply demonstrated and today is recognized by the industry in the creation of separate geologic staffs as fundamental units in the large producing organizations.

Fig. 5
Clinometer Compass

Fig. 6
Abney's Level

The Verschoyle Transit (*Fig. 7, page 6*) combines the useful features of the Abney's level, prismatic compass and clinometer. This is not a complicated, delicate instrument, liable to derangement or deterioration, but is thoroughly serviceable and highly suitable for accurate survey work.

SURVEYING ANERIOD BAROMETERS

Aneroid Barometers find application in geologic methods involving measurements of relative elevations. They are used also to determine dips where this measurement is expressed in feet per mile. The Aneroid Barometer consists essentially of a metal vacuum chamber which responds sensitively to changes in atmospheric pressure, and the practical application of this instrument is based on the decrease in atmospheric pressure with increasing altitude above sea level.

While aneroids are recommended primarily for reconnoissance work, their use is not necessarily limited to this application. Lahee, discussing the degree of accuracy of the barometer method of field mapping, in his book on "Field Geology" states: "The reader will perceive that the barometer method is highly elastic. It can be made slow and fairly precise, or rapid and less accurate. In other words it may be adapted to both detail and reconnoissance mapping. Under ordinary circumstances, whether progress be slow or rapid the average relative error may be made less than 1 vertical in 1000 horizontal, which usually is less than the variations in thickness of the strata."

The need for an accurate and reliable barometer is apparent. The Surveying Aneroid Barometer (*Fig. 8, page 6*) is characterized by special construction and design to conform in every way possible to the ideal requirements for an instrument of this type. It is especially adaptable for readily ascertaining slight variations in gradients, levels, etc. Its readings are taken rapidly and easily. Uniform graduation of scale admits of sub-divisions by a vernier, hitherto impracticable owing to the altitude scale in common use being a gradually diminishing one. Special leather carrying cases are provided with aneroids, which make their transportation in the field a matter of comparative ease. The success and

Exploration or Surveys for Petroleum

In exploration or investigational work for prospective oil areas, the geologist usually notes two distinct types of evidence which may or may not be apparent to the unskilled observer. These may be classified as (1) direct, and (2) indirect.

The direct indications may be observed in oil seepages, oily accumulations on springs or ponds, or outcrops of sand impregnated with petroleum. These conditions, however, are now generally regarded as unusual and are seldom encountered in present-day investigations in the United States.

Fig. 7
Verschoyle Transit

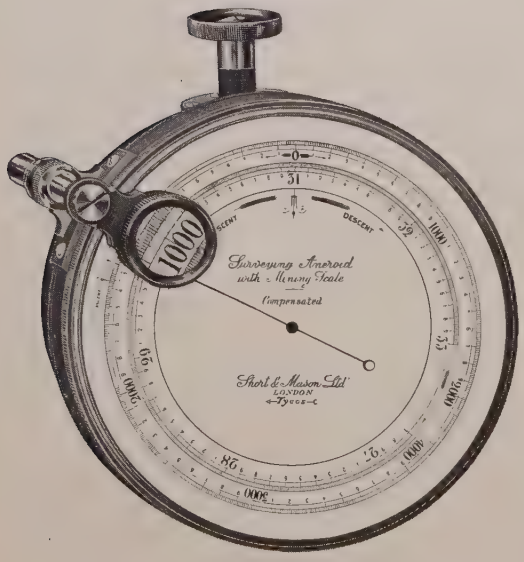


Fig. 8
Surveying Aneroid Barometer

popularity of Surveying Aneroids in field practices are evidenced by their extensive use among geologists, engineers and surveyors.

In the development and application of the Surveying Aneroid it has been the aim to make improvements from time to time which would render instruments more practicable and more serviceable to the user. For that reason, in 1925 a device was developed whereby a Surveying Aneroid has all the advantages of a movable altitude scale and all the safety of a fixed altitude scale.

New features which have been added to Surveying Aneroids simplify greatly the method of taking altitude readings. In the past, with the fixed altitude scale, it was necessary to make certain mathematical corrections in determining altitudes, inasmuch as the 31 inches of pressure and "0" feet of altitude were immovable, being engraved on the same dial plate. Since the hand never stands at 31 inches a certain amount (the equal in feet) had to be noted as the starting point.

With the new Surveying Aneroid, computations have been in part eliminated. The altitude scale is now adjustable, permitting the observer to set the instrument to the true altitude of the location simply by turning the scale so that the scale, altitude and pointer coincide, or the scale can be set so the zero is directly under the indicating hand when this method is preferred. When this is done the scale is locked by an adjusting screw. Thus the starting point is established and the observer, by noting the pointer at any altitude above or below the starting point, can determine the altitude without any calculations other than those made necessary by local changes in weather conditions.

While Surveying Aneroid Barometers are of necessity very delicate in their construction, yet the practical use of these instruments has been considered and they have been so constructed that they will stand the usual amount of abuse which surveying instruments are subjected to in carrying them on foot or in an automobile over bad roads and a rough country. Surveying Aneroids have been carried over all the inhabited globe, shipped in trunks, handled as hand baggage on trains, stagecoaches

The discovery of indirect evidences is usually the end towards which scientific efforts of exploration are directed. The underground folding and character of rock which may be conducive to the accumulation of oil or gas may be reflected in the curvature and nature of the outer or surface strata. The proper understanding and interpretation of surface conditions can at times be had only through extensive and comprehensive geologic surveys. Geologic field work in the above relation involves a study of the rocks, location of outcrops, determination of directions, vertical distances, horizontal distances, slopes, angles, etc. and the plotting of all geologic data on maps. By a careful correlation and mapping of surface indications, the geologist is able to determine with a fair degree of accuracy the structure of the ground underneath. In this way, if oil and gas are present the point of their occurrence may be estimated and the most favorable areas indicated.

Fig. 9
Round Pocket Reflecting Prism Level

Fig. 10
Square Pocket Reflecting Prism Level

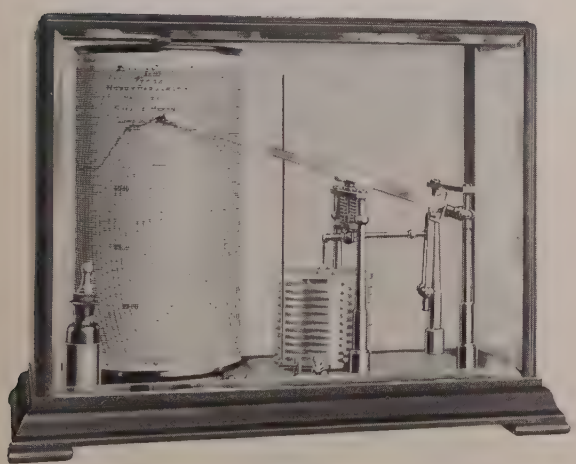


Fig. 11
Barograph (Recording Barometer) with Open Chart and Highly-Sensitive Movement

pack-horses and automobiles, without injuring them or causing error in their readings. Because of the painstaking care used in their manufacture they are exceedingly quick to respond when taken from one altitude to another. It is not necessary to wait a long time for the instrument to "settle".

Lightness, compactness, and ease of portability all have been considered in their manufacture, without overlooking the essentials of durability and accuracy.

THE BAROGRAPH (RECORDING BAROMETER)

It is evident that if a barometer is left in one place for 24 hours the needle will alter its position on account of local variations in atmospheric pressure. The altitude readings as indicated by the surveying aneroid in actual surveying are therefore incorrect. By knowing the effect of weather changes on the barometer reading however, the indications of the surveying aneroid may be compensated for this condition and the observed readings thus made to represent true differences in elevation.

In some cases the operator determines the compensating factor by reference to the record made by a barograph. This instrument is a recording aneroid barometer, which gives not only the extent of weather change but the time of its occurrence also. Where such a record is desired the highly-sensitive Barograph (*Fig. 11, page 7*) is recommended for stationary use, either at the home station of a traverse or near the center of the region to be surveyed during the day. This instrument has a remarkably sensitive movement and an extremely open chart, and furnishes a record of even the slightest change in atmospheric pressure. Slight variations hardly visible on an ordinary barograph chart are read easily from the chart of this instrument.

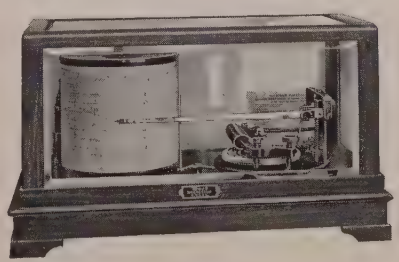


Fig. 12
Barograph (Recording Barometer)

Drilling Operations

In the actual testing of the geologic structure for oil or gas, three types of drilling may be employed, each having its peculiar advantages. These may be classified as (1) The Cable-Tool Method, whereby the rock is drilled or cut away by the alternate lifting and dropping of a heavy steel bit hung on a stretched rope or cable; (2) Rotary Drilling, which is accomplished by the rotation of a fish-tail bit screwed firmly to the lower end of a cable or pipe; (3) Core Drilling, which involves the rotation of a cutting tool made of a hollow soft-steel cylinder, the lower or cutting edge of which is set with black diamonds or special cutting alloys projecting slightly beyond the outer and inner edges of the cylinder. Stillite and other alloys are used on core bits.

Drilling is done usually by either the cable or the rotary method. Core, or diamond, drilling is generally employed for prospecting purposes.

Proper conditioning of bits is of paramount importance in oil-field work. Subjected as it is to the ordinary strains and usages attendant on drilling, the bit or drill must not only be constructed of the most durable steel, but must also be subjected to the proper methods of sharpening and tempering, in order to utilize fully the inherent qualities of its makeup. Improper tool dressing is costly both from the standpoint of deterioration and time consumption. It has been estimated that approximately 25% of the total drilling time is consumed in changing or replacing dull bits. An article by Mr. Shapiro of the U. S. Bureau of Mines (Serial No. 2712) on "Temperature Control System for Dressing and Tempering Fish-Tail Bits" shows that this time can be reduced to a minimum and the life of the bit prolonged by correctly applying the metallurgical principle that when steel is heated to a temperature slightly above its critical point and suddenly quenched, it will be harder and tougher than if quenched from any other point. By the "critical point" is meant that temperature at which the steel undergoes a complete change in its internal structure.

Instruments Applicable to Drilling Operations

PYROMETERS

The method of tempering using the lead bath is at present being used for hardening fishtail bits, re-cut and recarburized rockbit cones, slips, rotary shoes and other small parts. The temperatures usually maintained for tempering (hardening) are between 1380° and 1500°F. In carburizing rock-bit cones, temperatures as high as 1750°F. are used, this being done in a carburizing pot.

The High-Resistance Portable Indicating Pyrometer (*Fig. 13, page 8*) with base-metal Angle-Stem Thermocouple (*Fig. 15, page 8*) is recommended for oil-field use in tempering operations using either the molten-lead or salt bath. The High-Resistance Portable Pyrometer is a compact and durable instrument, can be transported readily without fear of injury, and does not have to be accurately

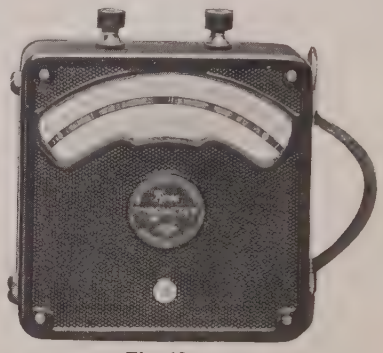


Fig. 13
High-Resistance Portable Indicating Pyrometer. For indicating temperature in lead baths.

Fig. 14
Low-Resistance Dial-Type Indicating Pyrometer
Used only with a single thermocouple, for measuring the temperature of one furnace. Built to meet the demand for a durable, reliable, low-priced indicating pyrometer.

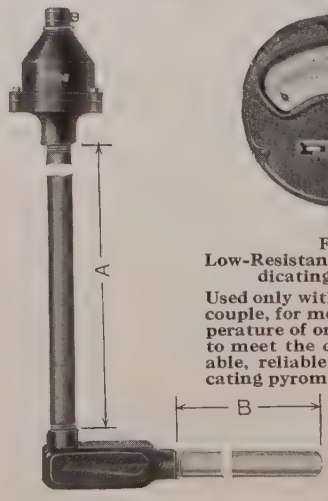


Fig 15
Angle-Stem Thermocouple for application in molten-lead bath.

Correct heating of the bit is accomplished in field practices by immersing the bit in a bath of molten material maintained at a temperature dependent on the composition of the steel being treated. Experiments with temperature control baths have brought out certain advantages of a molten-lead bath over a bath of molten salt alone. In this case, however, the molten lead is covered with a layer of salt to prevent oxidation of the lead at high temperatures. Uniform and thorough heating to the proper temperature, with a subsequent quenching in an oil bath and then in a water bath, imparts to the bit the maximum qualities of durability and hardness.

The advantage of the molten-lead bath over old methods in tempering operations as given by Mr. Shapiro may be briefly summarized in part as follows:

The method supplants the oil-field furnace.

The bit is treated evenly, uniformly and thoroughly.

Possible oxidation, overheating, or burning is eliminated.

Only that part of the bit submerged is heated.

All guess-work is eliminated. The temperature of the bath is shown at all times by the pyrometer.

Fig. 16
High-Resistance Wall-Type Indicating Pyrometer

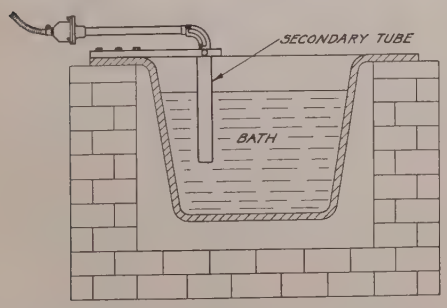


Fig. 17
Standard Base-Metal Angle-Stem Thermocouple with Secondary Protection Tube, on Metal Bath

leveled in taking readings. Where more-or-less permanent installations in shops are desired, the High-Resistance Wall-Type Indicating Pyrometer (*Fig. 16, page 9*) is recommended as the ideal instrument.

Portable and Wall-Type Indicating Pyrometers have sensitive but durable, jeweled and double-pivoted, high-resistance millivoltmeter movements. The instruments are direct-reading and there are no batteries to renew, no slide-wires to adjust or suspensions to break, thereby eliminating several possible sources of trouble and error common to this type of instrument. These pyrometers are equipped with dust-and-moisture-proof metal cases, have long open scales and knife-edge pointers for close readings. They can be supplied in standard ranges, 0-1800°F., 0-2200°F., 0-2400°F., with scale divisions of 20°. Special scales can be furnished also for any range desired. Automatic internal cold-junction compensation is furnished on the instruments when specified, thus making a most reliable and accurate device for use in carburizing and tempering.

In permanent installations where great accuracy is not required, the Low-Resistance Dial-Type Indicating Pyrometer (*Fig. 14, page 8*) meets the demand for a durable, reliable and low-priced instrument.

INDICATING BAROMETERS

In drilling operations, where a predetermined knowledge of weather conditions is desirable, these instruments (*Fig. 4, page 4*) will find ready application as weather forecasters. They are simple to read, have complete forecasts plainly shown on the dial, and are characterized by sturdiness of construction and portability, which makes them particularly adaptable to field practices.

The Barograph (Recording Barometer) (*Fig. 12, page 7*) is a different type of weather forecaster. It writes tomorrow's weather in ink on a simplified chart easily read and interpreted. With each instrument are furnished daily forecast cards corresponding to the different points on the recorder chart.

Oil Wells

When the oil-sand, or porous reservoir is penetrated by the drill, the oil may at the outset flow strongly from the well under its own high gas pressure. Wells of this type are characterized as flowing wells, or "gushers", and are a spectacular feature in many oil fields. In the United States wells have been struck with an initial daily production as high as 30,000 bbls. of oil. In some of the Mexican fields initial production from certain wells has amounted to 100,000 bbls. daily, with a pressure of 500 lbs. per square inch, while the record well, struck near Tampico, Mexico, produced 260,000 bbls. of oil the first day of flow.

In the production of oil, where there is no natural flow, or where the natural flow has abated due to a decrease in gas pressure or a depletion of the oil sand, the oil is brought to the surface by means of pumps. Wells of this type are called pumping wells and are in evidence mainly in the older fields.

Fig. 18

Recording Thermometer

Instruments Applicable to Oil Wells

In the case of producing wells, a knowledge of existing temperatures and pressures is an aid to the correct understanding and interpretation of well characteristics. The term "pressure control" is used in preference to the old term "back pressure" as applied to the regulation of the flow of gas and oil from the well. In order to determine the maximum flow efficiency of a well, both the flow, or tubing pressure, and the casing pressure must be known. Both the tubing and casing pressure are dependent on the pressure in the oil sand, so that under normal conditions the decline in tubing and casing pressures directly reflect the decline in rock pressure. By rock pressure is meant the pressure in the sand. A rapid decline in casing and tubing pressure would indicate a consequent short-flowing life of a well.

In order to conserve a pressure in the sand, orifices of various sizes are installed at the well head. For example, decreasing the size of the orifice would tend to increase both tubing pressure and casing pressure, which in turn would retard the decline of pressure in the oil sand. By careful manipulation of the orifices, or flow nipples as they are commonly termed, the maximum flow of oil can be obtained with the minimum decrease in pressure. Records of the pressures are therefore very important for determining the most efficient way to flow oil wells.

The Recording Pressure Gauge (*Fig. 19, page 11*) will give a continuous record of pressure maintained and thereby serve as an indication of efficiency in oil recovery as related to this particular factor.

A knowledge of the temperature or change in temperature of the oil is recognized as an aid in forecasting definite trends or tendencies in a flowing well. It is a peculiar fact particularly noticeable in some of the mid-continent fields that just preceding the entrance of water to a well the temperature of the oil rises appreciably. This temperature rise may last over a period of several weeks or may

The Air or Gas Lift System

Comparatively recent developments in the production of crude petroleum have brought about the application of the air or gas lift system for flowing wells. With other conditions favorable this system is being applied to wells where oil is standing in the hole and the flow has subsided or abated, due to the shortage of natural-gas pressure.

The air or gas lift system may be considered one of the most important features in connection with oil production today. In many cases where it has been applied it has taken wells off the pump, it has made commercial producers of wells hitherto considered practically dead, and it has increased the daily output of wells by several hundred per cent.

In the operation of the air or gas lift, compressed-air or gas is sent down the well through the tubing or casing, under a predetermined pressure. Upon being released at the bottom, in the body of the oil, the gas naturally expands and carries the oil with it towards the top of the well. The accomplishment of this system is based on the aerating effect of the gas when introduced into the body of the oil.

Repressuring Oil Sands

Another system involving the use of compressed-air or gas for stimulating the recovery of crude is that in which air or gas is introduced into certain "key" wells in a pool and by force tends to drive the oil from the oil sand into the surrounding wells.

Fig. 19

Recording Pressure (or Vacuum) Gauge.
This instrument in its bi-record type is widely used in gas-lift systems for recording on the same chart both the air or gas-line and flow pressures of oil wells.

occur for a few days only. The Recording Thermometer (*Fig. 18, page 10*) will furnish a continuous record of temperatures of the oil from the well, showing both the slightest fluctuation or change and the time of its occurrence.

The Combined Recording Thermometer and Pressure Gauge (*Fig. 56, page 29*) will furnish on a single chart corresponding and continuous records of both temperature and pressure in the line from the well, with each record traced in a different color ink. These instruments are furnished with charts showing either daily or weekly records of temperatures and pressures.

Instruments Applicable to the Air or Gas Lift System

Among the important factors in connection with air or gas lift installations is that of pressure. If too much pressure is being applied the air or gas will pass through the oil without materially assisting it to rise; if too little pressure is being used, the oil will not rise, or will flow in surges.

The Recording Pressure Gauge (*Fig. 19, page 11*) is an all-important adjunct in determining and maintaining the most efficient conditions for flowing wells by the air or gas lift system. This instrument is furnished also in the bi-record type, which gives records on a single chart of the pressures in the air or gas supply line and in the flow line, each record being traced in a different color ink, providing invaluable data easily read and interpreted.

Instruments Applicable to Repressuring Methods

In repressuring methods, the Recording Pressure Gauge (*Fig. 19, page 11*) is applicable for showing continuous records of pressures when this measurement is a factor.

Oil-Field Emulsions

Where water is encountered in an oil field the production of crude is sometimes accompanied by the formation of the oil-field emulsion, which is essentially a mixture of water in oil. Oil-water emulsions are commonly known in oil-field parlance as "BS", or "cut oil".

The marketability of crude is vitally affected by the presence of emulsions. Pipe-line companies generally refuse to handle crude which seemingly contains "BS", owing to its viscosity, with the attendant clogging effect in the lines, and the amount of water present must be at a predetermined minimum. The difficulties in refining also forbid the operator using this product in his stills. The presence of the emulsion was for a long time taken as a matter of course and the operator was concerned more with disposing of it than with methods for separating it into oil and water.

Emulsions, or "BS", are usually formed as a result of mechanical agitation, whereby particles of water are dispersed throughout the body of the oil. In some cases these droplets of water are comparatively large and their suspension is due primarily to the marked resistance offered by the viscosity of the oil towards their segregation. The breaking of an emulsion of this sort may be accomplished simply by allowing the mixture to stand sufficiently long, until the water through gravity has had time to settle out.

The more common type of emulsion is that known as a "true" emulsion, which cannot be broken down even by long standing. In this mixture droplets of water microscopic in size are covered with a protective film of oil which prevents coalescing. No separation of the oil and water in this case can be effected unless the protective film surrounding the water droplets be ruptured, and the breaking of this film is the object at which all efforts at demulsifying or dehydrating are directed.

Crude petroleum frequently contains both of the above types of emulsions, and the term "cut oil" in its stricter sense is applied to mixtures of the latter type.

KEY	DESCRIPTION
C-2	ANGLE-STEM THERMOMETER
P-15	TEMPERATURE REGULATOR
R-1	1/8" GAS OPERATING LINE
R-2	PRESSURE GAUGE
R-4	STRAINER
R-6	STOP COCK (1/8")
R-7	PET. COCK (1/8")
S-3	CRUDE OIL INLET
$S\text{-}3_a$	GAS FROM LEAD LINE MANIFOLD
$S\text{-}3_b$	GAS SUPPLY TO BURNERS
$S\text{-}3_c$	" " TO PILOT BURNER
S-5	HAND VALVE
S-6	CHECK VALVE
T-1	DIRECT ACTING DIAPHRAGM VALVE
U-1	BOILER TYPE TREATING PLANT
U-2	CHEMICAL FEED SYSTEM

SYSTEM OF AUTOMATIC TEMPERATURE CONTROL APPLIED TO BOILER TYPE OIL TREATING PLANT

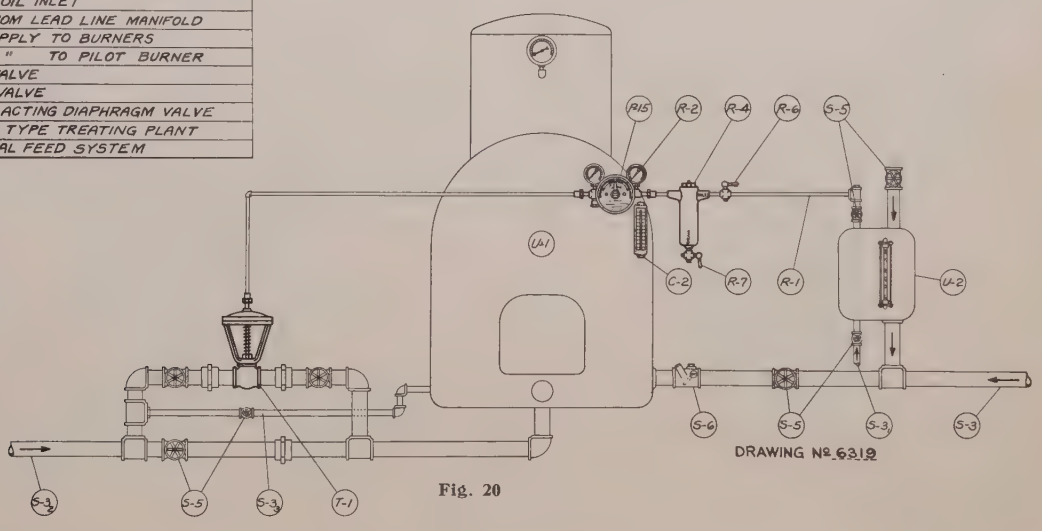


Fig. 20

Crude-Oil Treating Processes

DEHYDRATION BY HEAT

One of the oldest and most common methods in use for the breaking down of emulsions is to heat the crude. This allows the many tiny particles of suspended water to coalesce, and through force of gravity they soon settle to the bottom. The heat tends also to decrease the viscosity of the crude, thus causing less resistance to the tendency of the water particles towards segregation. Dehydration systems of this type sometimes employ steam as the heating agency. Tanks are constructed with steam coils in the bottom and these coils usually are immersed in water through which the crude to be treated is forced from the bottom. In this way the crude is not heated directly by the steam itself, but through contact with the hot water. Further circulation through another tank similarly constructed tends usually to complete the dehydration process.

Dehydration is sometimes carried on at much higher temperatures than would occur in the preceding method. In many cases the crude is subjected to temperatures sufficiently high to drive off the water as steam, which is condensed with the lighter petroleum distillates.

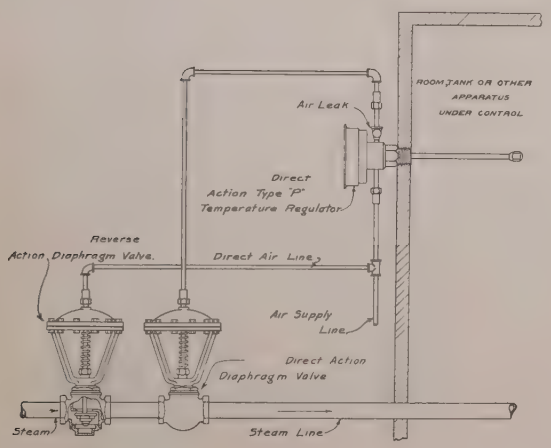


Fig. 21

Installation of Direct-Acting Expansion-Stem-Type Temperature Regulator and Direct-Acting and Reverse-Acting Diaphragm Valves.

Instruments Applicable to Oil-Treating Plants

In dehydration processes involving the use of heat, the maintenance of proper temperatures in the oil being treated is in a large measure essential to the success of the operation. The heating of the oil in many cases is carried out in a modified type of boiler, and gas or oil is used as the heating medium.

Automatic temperature regulation here insures the maintenance of the correct temperature throughout the treating process and thereby gives a uniformity and consistency of operation which could only with difficulty be duplicated by manual control.

Where single-pipe oil or gas burners are used, boiler temperatures are controlled automatically by means of Expansion-Stem-Type Air-Operated Temperature Regulators (*Fig. 22, page 14*). This regulator in conjunction with a Direct-Acting Diaphragm Valve (*Fig. 23, page 14*) in the fuel supply line automatically maintains a throttling control of the supply of fuel to the burner, dependent on the temperature desired for the oil being treated. A reverse-acting diaphragm valve in addition, in this installation, will automatically shut off the heating medium in case of the failure of the air supply which operates the instrument.

The operation of the Expansion-Stem-Type Temperature Regulator is based on the expansion and contraction of a metal tube comprising the regulator stem, which in the installation (*Fig. 20, page 12*) is inserted in the treating tank. The movement of the stem opens or closes an air valve in the body of the instrument and thus regulates the air supply actuating the diaphragm valve in the fuel supply line. The stem of the regulator can be protected by a lead coating, as a safeguard against possible corrosive action of the medium with which it is in contact.

The Expansion-Stem-Type Temperature Regulator is so sensitive that if it is adjusted to a temperature slightly below that of the human body (98.6°F.), placing one's hand on the stem will cause it to operate. In actual

CHEMICAL DEHYDRATION

The use of chemicals in the breaking down of emulsions has become common practice in many fields.

In this process the breaking or rupturing of the interfaces of the particles of emulsified water and crude is accomplished by chemical action. One of the most successful methods that has been developed is the use of Tret-O-Lite and is that known as the Brady process. The crude to be treated flows through a line in which is placed a special type of apparatus, which is adjusted to allow a given amount of the treating agent to be added to the crude as it passes through. The crude so treated passes immediately to a special-type boiler, where it undergoes heat treatment at a definite temperature for a definite period. From here it passes to a "settling tank" where separation of the water takes place.

ELECTRICAL DEHYDRATION

The use of electrical methods in breaking down emulsions is being employed rather extensively in most California and some Gulf-Coast fields. The principle of the Cottrel, or the "PR" process, involves the subjection of the crude to a high-potential alternating field; the oil films separating the minute water particles are ruptured, and the water droplets coalesce and settle out. The crude to be treated may previously undergo a heat treatment before it is subjected to the electrical process.

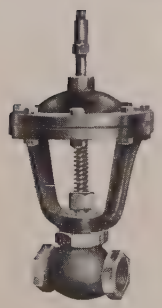


Fig. 23
Diaphragm Valve used with Expansion-Stem-Type Temperature Regulators

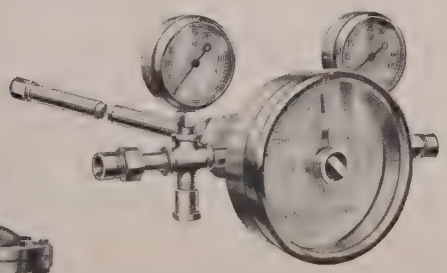


Fig 22
Expansion-Stem-Type Temperature Regulator used for controlling temperatures in boiler-type treating plants, steam stills, dephlegmators, knockout boxes, etc.

use the regulator stem will function on a temperature change of from ¼ degree to ½ degree F.

This System of Automatic Control is extensively and successfully used in many boiler-type treating plants, and (*Fig. 20, page 12*) shows a typical application in the mid-continent field.

Self-Acting Temperature Regulators (*Fig. 35, 37, page 19*) are used to some extent in boiler-type treating plants. Many operators prefer this controller, because compressed air or gas is not essential to its operation and its simplicity and sturdiness of construction make it particularly adaptable to outdoor installations. It should be borne in mind however that this instrument is applicable only where temperature control within close limits is not essential, and that equally close and consistent results cannot be expected from an instrument of this type as from an air-operated temperature regulator.

In the dehydration of emulsions by heat, as carried out in tanks equipped with steam coils in a manner previously described, proper treating temperatures are likewise maintained by the Expansion-Stem-Type Air-Operated Temperature Regulator (*Fig. 22, page 14*). This regulator, with its sensitive member inserted in the hot water through which the oil is forced, effects control by automatically regulating the admission of steam to the coils by means of a diaphragm valve in the steam supply line.

Recording Thermometers (*Fig. 18, page 10*) are recommended for showing continuous records of temperatures at which treating operations have been carried out. Industrial Thermometers (*Figs. 24, 25, page 15*) find ready application in all treating processes where temperature indication is a factor.

INSTRUMENTS APPLICABLE IN THE ELECTRICAL DEHYDRATION OF EMULSIONS

Industrial Thermometers (*Figs. 24, 25, page 15*) are characterized by standardized scales, cases and stem forms, making them particularly adaptable to preheater applications. Recording Thermometers (*Fig. 18, page 10*) will show continuous records of temperatures in crude-oil-emulsion treaters or preheaters.

Transportation of Crude-Oil Through Pipe Lines

The transportation of crude oil from the well, either to the refinery direct or to storage, is generally accomplished by the use of pipe lines. Practically all pipe-line companies engaged in the transportation of petroleum have a main or trunk line and in addition extensive systems of gathering lines. These are provided for the purpose of collecting the oil from the producer's tanks and running it to a central storage point, or to some point where it can conveniently enter the main trunk line.

Gathering lines may be laid on the surface of the ground, but main trunk lines generally are buried at any depth of from a few inches to several feet.

Oil is forced through the lines by means of pumps operated either by steam, internal-combustion engines, or electrically, and pump stations are located at varying distances apart, dependent on the topography of the country through which the line is laid and the viscosity of the oil being transported.

Fig. 25
Straight-Stem Industrial Thermometer

Fig. 24
Oblique-Angle Industrial Thermometer with Stem Vertical

Instruments Applicable to the Transportation of Crude Oil Through Pipe Lines

In laying pipe lines, surveys are necessarily made of the route for the line, and maps are prepared showing exact locations, grades and contours. Surveying Aneroids (*Fig. 8, page 6*), Surveying Compasses (*Fig. 3, page 4*), Abney's Level (*Fig. 6, page 5*) and the Improved Pocket Reflecting Prism Level (*Figs. 9 and 10, page 7*) are recommended where instruments of either type are desirable, the same as in any civil engineering or geologic field practice.

Industrial Thermometers (*Figs. 24, 25, page 15*) and Cup-Case Thermometers (*Fig. 97, page 55*) find practical application in pipe-line systems for accurately showing oil temperatures at any desired location. Recording Pressure Gauges (*Fig. 19, page 11*) are recommended for showing a continuous record of pressures existing in pump lines, both in transportation and loading.

DIESEL ENGINES

The Diesel engine is coming into extensive use at pump stations in many parts of the United States. In the operation of the Diesel engine, correct knowledge of the exhaust-gas temperatures is at all times necessary in order to check up on the operating efficiency and anticipate possible break-downs. Successful operation of the Diesel multi-cylinder engine under all load conditions is primarily dependent on the uniformity of work-load distribution on the cylinders, and the existence or non-existence of this condition is reflected in the temperatures of the exhaust gases from the cylinders. When the load is evenly balanced, exhaust-gas temperatures from all cylinders are the same. In an unbalanced load, exhaust-gas temperatures from the overloaded cylinder or cylinders are necessarily higher than from the others. An overloaded engine with an even distribution of load is evidenced in a uniform rise of exhaust-gas temperatures from each cylinder.

A sub-normal exhaust-gas temperature generally is evidence of a weak cylinder, receiving insufficient fuel and consequently inefficient in operation. If in this case the engine r.p.m. are held up to normal the remaining cylinders are doing more than their share of the work, which is detrimental.

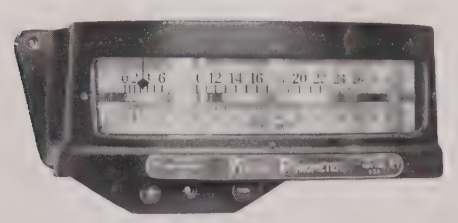


Fig. 26
High-Resistance Wall-Type Indicating Pyrometer for indicating temperatures in Diesel-Engine Exhausts, Still Furnaces, Fuller's-Earth Burners, etc.

Fig. 27
12-Point Rotary Switch

Fig. 28
12-Point Rotary-Switch Panel

The switching devices and panel-boards illustrated are used where it is desirable to show with a single Indicating Pyrometer the temperatures at a number of different points.

Fig. 29
Base-Metal Thermocouple designed for use on Diesel-Engine exhausts

On an evenly-operated Diesel two-cycle engine at "no load", exhaust-gas temperatures are approximately 125°-135°F.; at 25% overload, or full capacity, about 600°F. On a four-cycle engine this range is usually 250°F. at "no load", and 775°-800°F. at 25% overload, or full capacity.

The importance of the pyrometer as an essential part of the Diesel engine equipment is apparent. While the pyrometer does not indicate the exact nature of engine trouble, it does show its occurrence at once and thereby gives the signal for immediate investigation. Pyrometer equipment can be so installed as to permit the operator to read on a single instrument the temperatures of the exhaust gases from all cylinders. High-Resistance Wall-Type Indicating Pyrometers (*Fig. 26, page 16*) are particularly adaptable and specially recommended for Diesel engine applications. This instrument can be furnished in a standard range from 0°-1000°F., with a clear and open easy-reading scale. In all installations Base-Metal Thermocouples (*Fig. 29, page 16*) should be inserted in the branch from each exhaust valve and also in the common exhaust. These pyrometers are well constructed and are low in maintenance cost, due to the sturdiness of the thermocouples which are designed to give long and satisfactory service. Indicating Pyrometers can be furnished to give temperature readings 50 to 1000 feet away from the source of heat.

By the use of the Twelve-Point Rotary Switch (*Fig. 27, page 16*) as many as twelve thermocouples can be connected to the same pyrometer. The rotary switch is furnished also standard for six stations. A six-cylinder engine requiring six thermocouples can be provided with the six-point switch and one pyrometer; two six-cylinder engines requiring twelve thermocouples can be furnished with the twelve-point switch and one instrument. Two or more switches can be interconnected to take care of any number of points; e.g. two switches (six and twelve point) would have a capacity of eighteen thermocouple stations.

Rotary switches can be enclosed in dust-and-moisture-proof cases with connections at the back, suitable for either wall or panel-board mounting. Metal

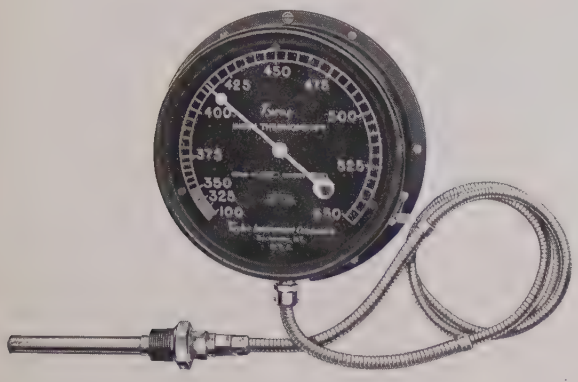


Fig. 30
Index Thermometer

Index thermometers are supplied as illustrated, except with dials graduated for temperature range specified.

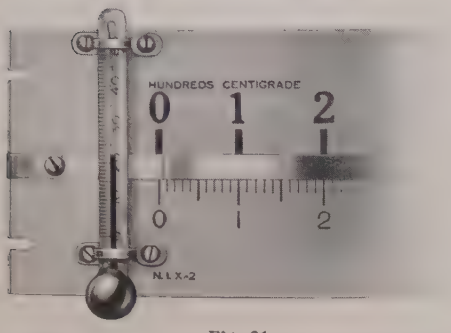


Fig. 31

Showing Thermometer used for cold-junction setting, attached to temperature scale of pyrometer.

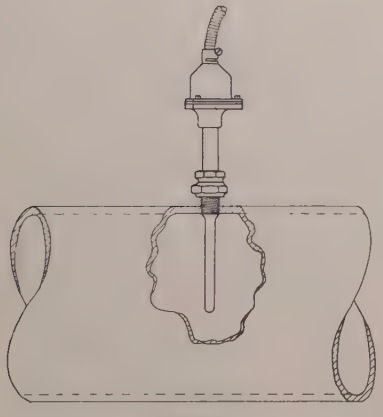


Fig. 32

Separable-Socket Base-Metal Thermocouple for Diesel-Engine Exhausts, Superheaters, etc.

Protection Cases can be furnished for standard panel-boards; Hardwood Protection Cases (*Fig. 43, page 23*) can be furnished standard for indicators only.

Attention is called also in this connection to the Push-Button Switchboard Panel (*Fig. 33, page 18*) which can be furnished standard to take care of as many as eighteen points.

Where temperature readings of Diesel-engine exhaust gases are carried out on schedule, Recording Pyrometers are applicable for showing a continuous record of exhaust-gas temperatures. This instrument can be furnished in the single-record (*Fig. 57, page 31*) or double-record type (*Fig. 42, page 23*), with standard chart range from 0° to 1200°F. Switchboards can be furnished with an extra set of terminals and necessary wiring connections for use with combined indicating-recording systems.

In the operation of the Diesel engine the observation of the temperature of the jacket-cooling water at the outlet point is equally important. Improperly functioning cylinders are evidenced in either a higher or lower water temperature than their companion cylinders. Index Thermometers (*Fig. 30, page 17*) are particularly adaptable for showing at all times the outlet temperatures of the jacket-cooling water. This instrument is made with a pointer which revolves over a full-circle dial and is used extensively where the usual type of indicating thermometer would be inconvenient to read, or constantly liable to breakage. The Index Thermometer can be located at any distance up to 75 ft. from the point where the temperature is to be measured. Finished as it is in dull instrument-black, with black dial and silver-deposited figures and graduations, it is adaptable to easy and long-distance reading.

Where it is convenient to read the thermometer at its point of insertion, or if for any other reason this type is preferred, Industrial Thermometers (*Figs. 24, 25, page 15*) are furnished in straight-stem or any angle-stem form as desired, for accurately showing temperatures in the cooling-water lines.

Where it is desired to maintain a log or record of an engine's operation, Recording Thermometers (*Fig. 18, page 10*) will furnish a complete and continuous record of jacket-water temperatures.

A feature of Recording and Index Thermometers is that they can be equipped with an electrical device which automatically rings a bell or lights a light, when a predetermined fixed or danger temperature has been reached.

Fig. 33
12-Point Push-Button Switchboard Panel

STEAM-DRIVEN AND ELECTRICALLY-DRIVEN PUMPS

In pumping operations where the steam pump is employed, the Air-Operated Pressure Regulator (*Fig. 62, page 35*) in conjunction with a diaphragm valve in the steam line to the pump will maintain the desired pressure in the line by regulating the speed of the pump. This instrument is similar in construction and design to the temperature regulator. It is operated by pressure from the controlled system expanding or contracting the metal capsular chamber and thus regulating the air supply operating the diaphragm valve.

In the case of electrically-driven pumps, constant line pressure is obtained by means of the Direct-Set Electric-Contact Pressure Control (*similar to Fig. 87, page 50*) which, in connection with a relay, serves to start or stop the pump in accordance with the operating pressure desired.

Recording Pressure Gauges (*Fig. 19, page 11*) are desirable adjuncts in all systems involving pressure and pressure control.

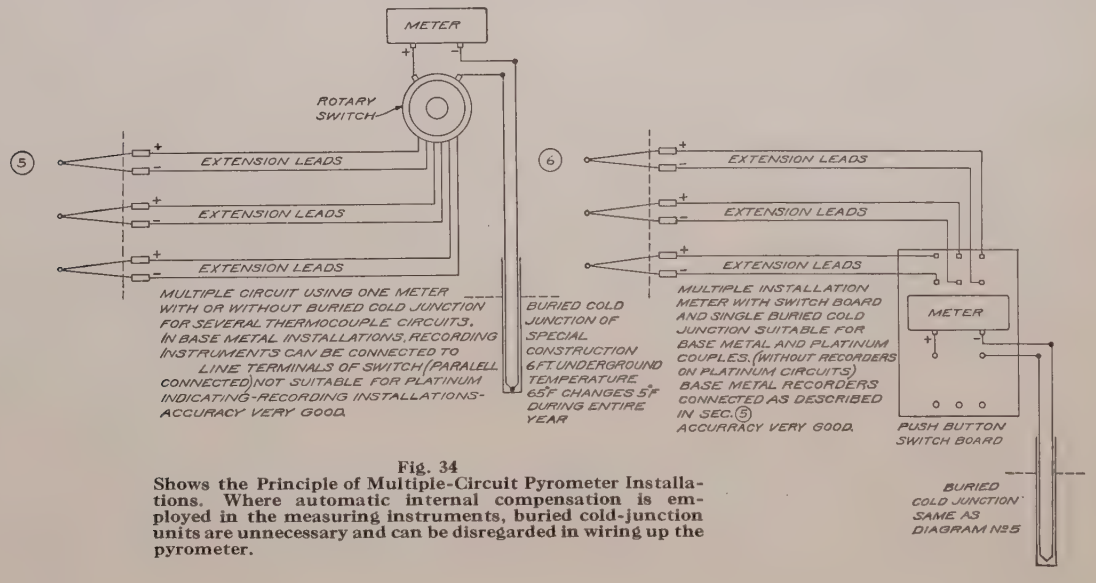

METER
ROTARY SWITCH
5
EXTENSION LEADS
EXTENSION LEADS
EXTENSION LEADS
MULTIPLE CIRCUIT USING ONE METER WITH OR WITHOUT BURIED COLD JUNCTION FOR SEVERAL THERMOCOUPLE CIRCUITS. IN BASE METAL INSTALLATIONS, RECORDING INSTRUMENTS CAN BE CONNECTED TO LINE TERMINALS OF SWITCH (PARALELL CONNECTED) NOT SUITABLE FOR PLATINUM INDICATING-RECORDING INSTALLATIONS- ACCURACY VERY GOOD.
BURIED COLD JUNCTION OF SPECIAL CONSTRUCTION 6 FT. UNDERGROUND TEMPERATURE 65°F CHANGES 5°F DURING ENTIRE YEAR
6
EXTENSION LEADS
EXTENSION LEADS
EXTENSION LEADS
MULTIPLE INSTALLATION METER WITH SWITCH BOARD AND SINGLE BURIED COLD JUNCTION SUITABLE FOR BASE METAL AND PLATINUM COUPLES. (WITHOUT RECORDERS ON PLATINUM CIRCUITS) BASE METAL RECORDERS CONNECTED AS DESCRIBED IN SEC. 5 ACCURACY VERY GOOD.
METER
PUSH BUTTON SWITCH BOARD
BURIED COLD JUNCTION SAME AS DIAGRAM N25

Fig. 34
Shows the Principle of Multiple-Circuit Pyrometer Installations. Where automatic internal compensation is employed in the measuring instruments, buried cold-junction units are unnecessary and can be disregarded in wiring up the pyrometer.

Storage of Crude Petroleum

Crude petroleum usually is stored above ground in cylindrical iron or steel tanks of convenient size to meet requirements. These tanks are characterized by special design and equipment in order both to preserve the crude in its original state over indefinite periods and to minimize fire hazards. They are located either directly at the wells to take care of the crude until it can be transferred to pipe lines, or are grouped together in what are known as "storage" or "tank" farms. An important consideration in tank storage is to prevent loss by evaporation. The extent of this loss is determined both by the quality of the crude being stored and the temperature during storage. The lighter the crude and the higher the temperature, the greater is the percentage of loss by evaporation.

Instruments Applicable to Crude-Petroleum Storage Tanks

Industrial Thermometers (*Figs. 24, 25, page 15*) are recommended for indicating the temperature of crude in storage. Recording Thermometers (*Fig. 18, page 10*) are recommended for giving a continuous record of crude storage temperatures where this data might be valuable as a matter of record or comparison.

Where it has been found economically practicable to control temperatures in the crude storage tanks by a water-spray cooling system, as is oftentimes applied to gasoline storage tanks, Capillary-Type Temperature Regulators (*Fig. 69, page 41*) are recommended for automatically effecting this control. This instrument, in connection with a diaphragm valve in the cooling-water line, automatically regulates the flow of the cooling water in accordance with temperature conditions in the tank.

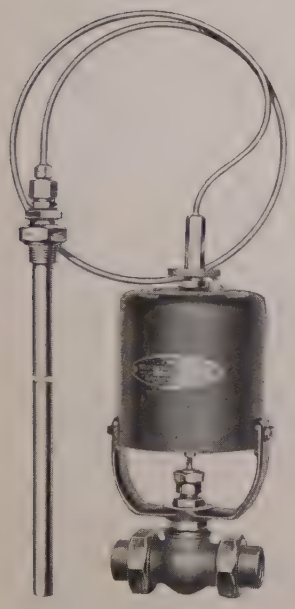


Fig. 35

Self-Acting Temperature Regulator for Controlling Temperatures in Boiler-Type Crude-Oil Treating Plants.

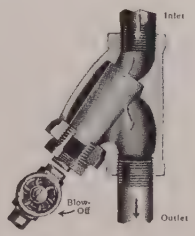


Fig. 36

Steam Strainer

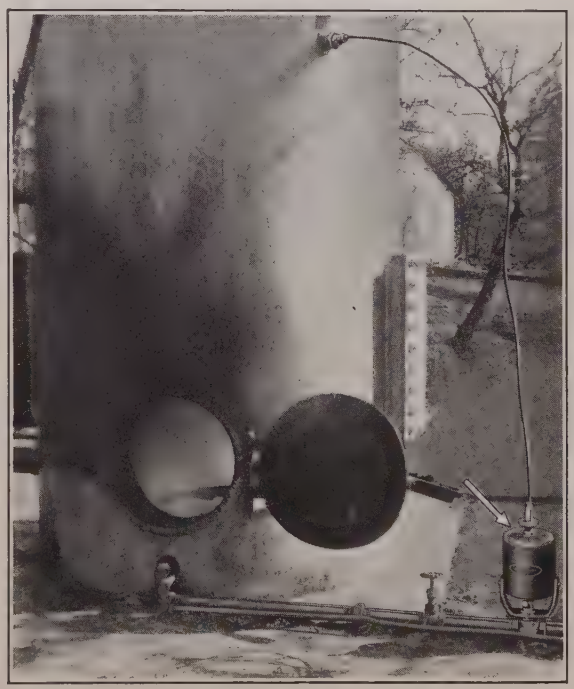


Fig. 37

Self-Acting Temperature Regulator Controlling Temperatures in Crude-Oil Treating System.

The Refining of Crude Petroleum

The refining of crude petroleum is simply a separation of the material into its component parts and a subsequent treatment to remove from these separated components the complex hydrocarbons, or impurities, the presence of which is detrimental to the finished product. Crude petroleum is the source of a great variety of commercial products, some of the more important being gasoline, kerosine, lubricating oils, paraffin wax, petrolatum, and heavier fuels. The production of the light motor fuels is generally considered of primary importance and the grading of the crude usually is based on its light-oil content as shown by gravity. The importance of lubricating oils, however, is recognized by the industry when it is considered that equipment for the production of finished lubricants and their allied products is astonishingly large. Not all refineries are complete in the sense that they can produce both the light oils and lubricants. "Skimming" or "topping" plants manufacture the light motor fuels and dispose of the residual oil either as fuel oil or to be used elsewhere in the manufacture of finished lubricants.

Petroleum refining is based on a process of distillation, whereby the various petroleum constituents may be separated and recovered by combination systems of vaporization and condensation, vaporization being accomplished by the aid of heat, directly or indirectly applied. In general the fundamental principles in refining are the same, and individual processes, while directed towards the same end, may vary due to the nature of the different crudes with which the operator has to deal. Usually the refiner has evolved methods which in accordance with past experience he deems best suited to meet his requirements.

Crudes may be grouped into three classes; (1) Those containing paraffin wax, known as paraffin-base crudes. (2) Those containing asphalt, known as asphaltic-base crudes. (3) Those containing both paraffin and asphalt, known as intermediate or mixed-base crudes.

Paraffin-base crudes are the source of many of our high-grade lubricants and cylinder stocks. In addition they generally are characterized by their high gasoline content. Refinery practices hereto applied are concerned with effecting the most complete separation of both the light and heavy products with the least damage possible to the heavier or lubricating stock. The refining of an asphaltic-base crude may be primarily directed towards the maximum recovery of the motor fuels, which in part is aided by the actual destruction or decomposition of the heavier products, in a manner later described. Certain refinery practices are naturally more suitable for paraffin-base than for the asphaltic-base crudes, and vice versa. The refining of a mixed or intermediate-base crude is in part characteristic of practices applied in the refining of both paraffin-base and asphaltic-base crudes.

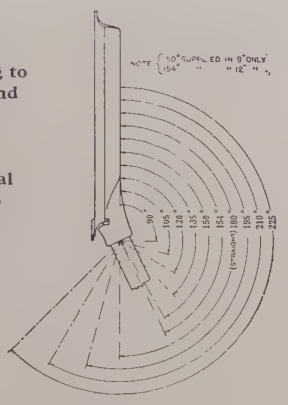
Refinery distillation processes can be grouped arbitrarily under several basic heads, classified in accordance with conditions and operating methods characteristic to each type. These are: **1**—Distillation by fire. (The term "distillation by fire" is here meant to imply distillation primarily by dry heat). **2**—Distillation by steam. **3**—Distillation under vacuum. **4**—Distillation under pressure, or "cracking processes".

The refining of a paraffin or intermediate-base crude may employ all the different distillation methods and also the subsequent basic processes involved in the general operation of a complete refinery. The refinery term "running to cylinder stock" is expressive of this procedure.

In the refining of an asphaltic-base crude and in some processes of refining a paraffin or intermediate-base crude, the oil generally is run down in fire stills. When the complete process is carried on by this method it may be designated in refinery parlance as "running to fuel oil", or "running to coke".

Distillation by Fire

The first step in refining may be accomplished by "fire distillation", wherein a still or a group of stills is charged with crude and heated directly by fire. In the case of a paraffin-containing crude, the elementary products from this distillation may be gasoline, naphtha, kerosine and gas-oil. Gasoline and naphtha fractions being of higher volatility are naturally driven off first and the vapors condensed. From the condenser the distillates (condensed vapors) pass through a so-called "look box" where the operator is able to observe the stream and take samples of the distillates as desired. As distillation proceeds the temperature of the crude continues to rise and fractions of successively higher boiling points and lower A. P. I. gravities are driven off. The limits of the individual cuts are based on the gravity of the stream as observed at the "look box", but each cut, especially that of gasoline, is actually determined by the boiling points desired. The gravity is naturally a convenient index of the boiling point, but this relationship varies with different crudes. The different distillates are collected in separate "run-down tanks."



Plan of Angles Applying to 9-inch and 12-inch Angle-Stem Industrial Thermometers

Fig. 38

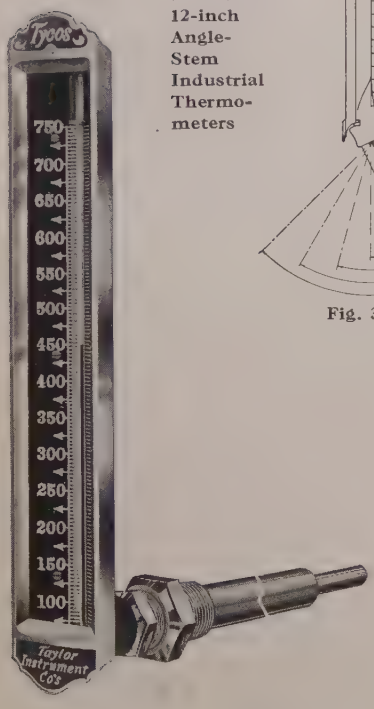


Fig. 39
Angle Still Thermometer with Separable Socket

Instruments Applicable to Fire Stills

In no industrial process is the element of temperature of more vital importance perhaps than in crude-oil refining, for it is this fundamental factor upon which the petroleum industry is based. A correct knowledge of distillation temperatures is essential to the proper understanding and maintenance of the most efficient plant procedure. A thermometer therefore (either indicating or recording) should be considered an essential unit of the still itself.

Industrial Thermometers (*Fig. 39, page 21*) give a clear and accurate indication of temperatures existing in crude-oil stills. These instruments are furnished in standard forms with correct design of bulb, connection, range and scale-case, making them particularly adaptable to still applications. Permanent accuracy in temperature measurement is insured through the proper annealing and aging of every glass thermometer tube.

Index Thermometers (*Fig. 108, page 59*) are recommended especially for still applications where on account of inaccessibility or inconvenience of observation a mercury-column thermometer is impracticable. A pointer revolves over a full-circle dial with evenly-divided scale, showing a clear and accurate indication of the temperature in the still.

Recording Thermometers (*Fig. 18, page 10*) are used extensively throughout the refining industry for recording still temperatures. These instruments show clearly and accurately every fluctuation of the temperature in the still and the exact time at which it occurred. Mercury-Actuated Recording Thermometers record temperatures as high as 1000°F. They are made with flexible connecting tubing which permits locating the case at a convenient distance from point of installation of the bulb in the apparatus. Recording Thermometers are characterized by a high degree of sensitivity and a sturdiness of construction which makes them particularly adaptable to still applications. Their high standard of efficiency and worth is evidenced in the fact that many refineries have practically standardized on them for use in their distillation processes.

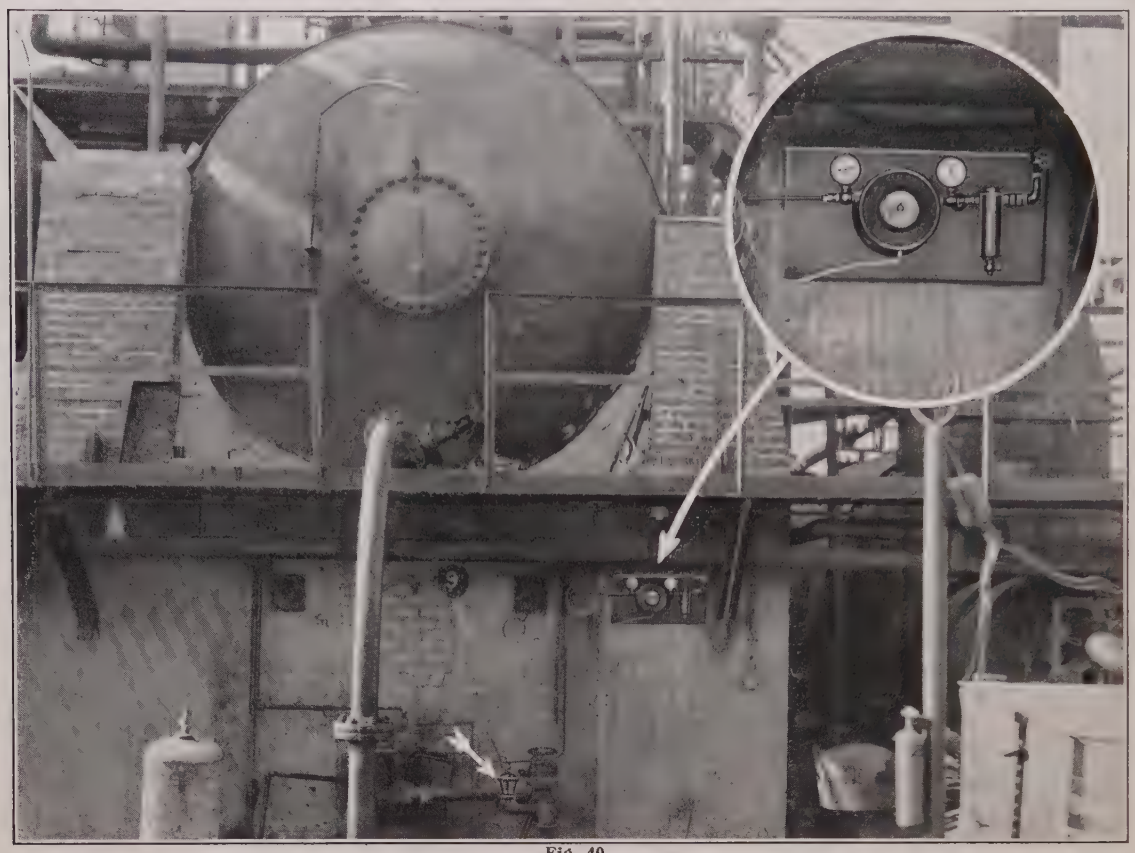


Fig. 40
Mercury-Actuated Regulator Controlling Temperatures in a Gas-Fired Crude-Oil Still

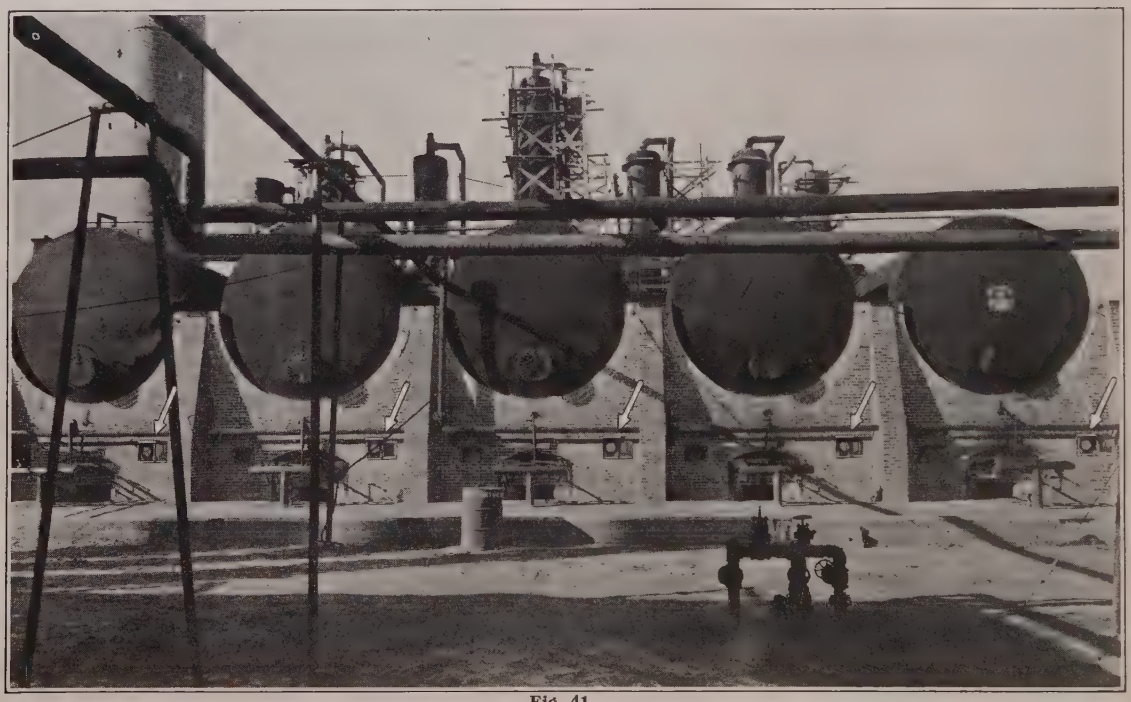


Fig. 41
Battery of Crude-Oil Stills Equipped with Recording Thermometers

Crude petroleum distillations sometimes are carried out as "batch" distillations in stills of the shell type. In this case each still is a complete unit in itself in that the gasoline, kerosine, gas oil, etc., are obtained successively from a single still as the temperature of the charge is continually raised.

The "continuous" process as opposed to "batch" distillation involves the continuous passage of the crude through a battery of stills, each of which is maintained at a temperature successively higher than the preceding one. The flow of the crude from still to still is in most cases actuated by gravity. Each still in the battery is operated at practically constant temperatures, and the gasoline, naphtha, kerosine and gas-oil cuts are taken from their respective stills. Continuous distillation is accomplished also in "pipe" or "tube" stills. In this process the crude is pumped continuously through a pipe-coil heater into an expansion chamber or evaporator, from which the vapors are taken off and the different fractions condensed.

Fig. 42
Duplex-Record Recording Pyrometer

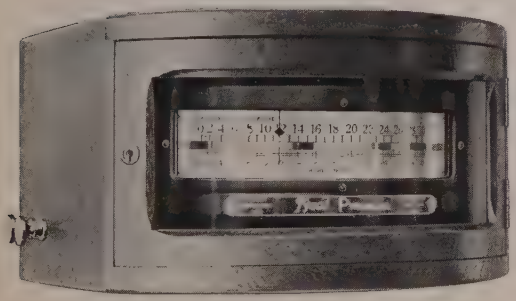


Fig. 43
Wall-Type Indicating Pyrometer in Wood Protection Case

Indicating and Recording Pyrometers are particularly adaptable and are recommended for application in either gas, oil, or coal-fired still furnaces for indicating or recording temperatures above 1000°F. Pyrometers of excellent material, workmanship, and design and having a guaranteed accuracy of one-half of one per cent of full-scale deflection can be obtained for measuring temperatures at a distance of from 50 to 1000 feet from the source.

The Indicating Pyrometer (*Fig. 26, page 16*) has a knife-edge pointer, giving a close reading over a long open scale. The Recording Pyrometer is furnished in both the single record (*Fig. 57, page 31*) and duplex-record (*Fig. 42, page 23*) types. In this instrument the knife-edge pointer is periodically depressed against a 50-day continuous-record ribbon chart. When depressed the pointer is intercepted by an impregnated inking thread, which is carried to the chart, making a dot. A succession of these dots makes a solid line with the appearance of being pen-drawn. With this method there is no possibility of ink being spilled on the chart and destroying the record.

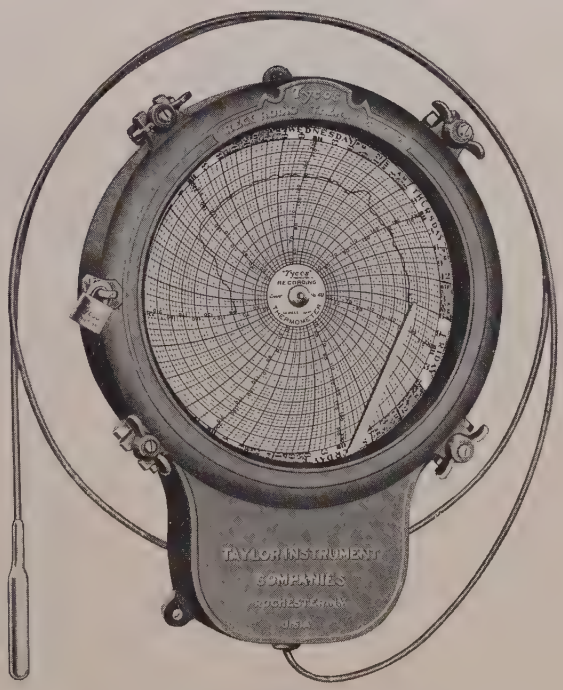


Fig. 44
Recording Thermometer Housed in Extra-Heavy Cast-Iron Fume-Proof Case. Specially Recommended for Still Applications

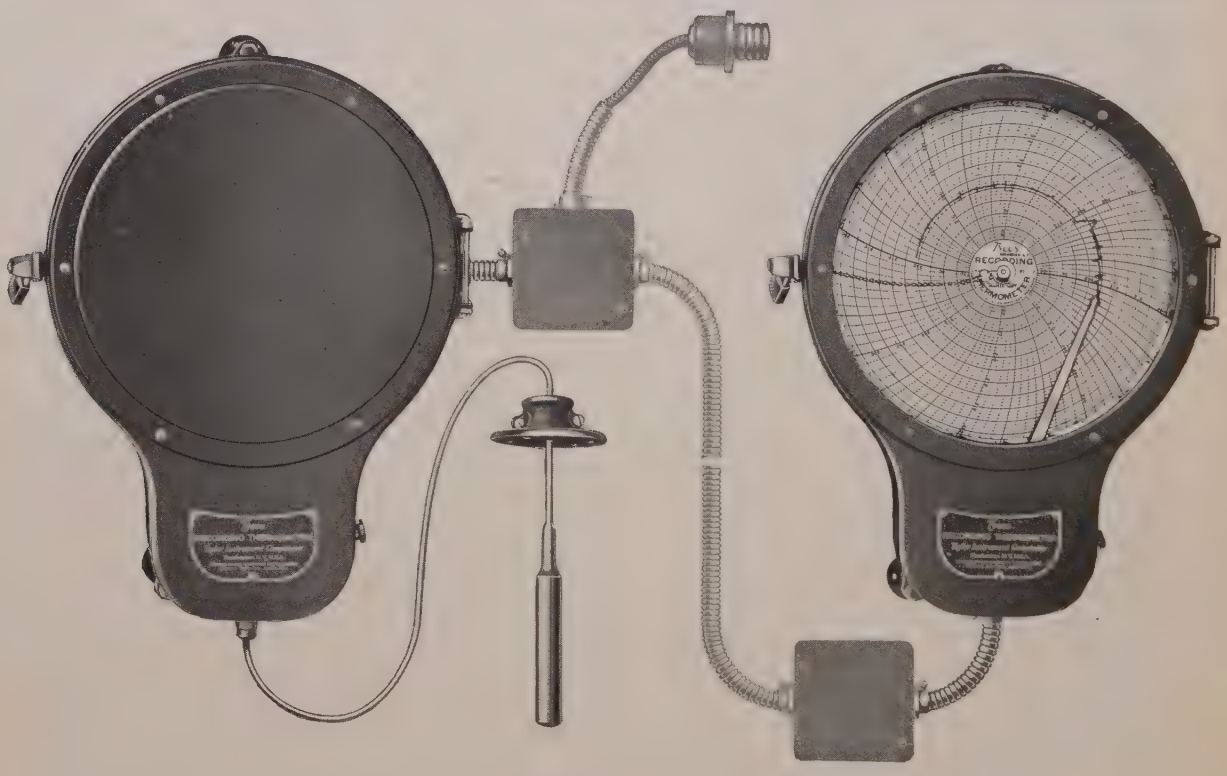
Fig. 45

Bi-Record Recording Thermometer. For recording temperatures in Oil Refining Processes.

In a tube or pipe still the Bi-Record Recording Thermometer (*Fig. 45, page 24*) shows on a single chart a continuous record of the temperatures of the oil on entering and leaving the heating coils.

Industrial Thermometers (*Fig. 39, page 21*) Index Thermometers (*Fig. 108, page 59*) and Recording Thermometers (*Fig. 18, page 10*) find equally important application in vapor lines from stills.

Distance-Reading Electric Transmitting Recording Thermometers (*Fig. 46, page 24*) are recommended for still applications where it is desirable to locate the recording instrument at a distance of several thousand feet or more in excess of that possible with the regular recording thermometer. The Distance-Reading Recorder is a mechanically simple, powerful and reliable instrument possessing the same degree of sensitivity and accuracy and involving the same essentials of construction as the regular recording thermometer.



Sending Station — Fig. 46 — Receiving Station

Distance-Reading Electric-Transmitting Recording Thermometer (or Gauge). Will record fluctuations in temperatures or pressures at remote distances.

In "fire distillations" as applied to a paraffin-containing crude, the recovery of the lighter products is in many cases aided by a sparing injection of steam against the inner bottom of the still. This is designed to effect better agitation of the still contents, which prevents local overheating; and also to eliminate decomposition or "cracking" of the crude.

"Skimming" or "topping" practices imply the removal of all the gasoline, kerosine, and part or all of the gas-oil content of the crude, or the removal of simply the gasoline fractions. In this latter practice straight distillations are naturally carried on at a lower temperature than where quantities of kerosine and gas-oil also are produced.

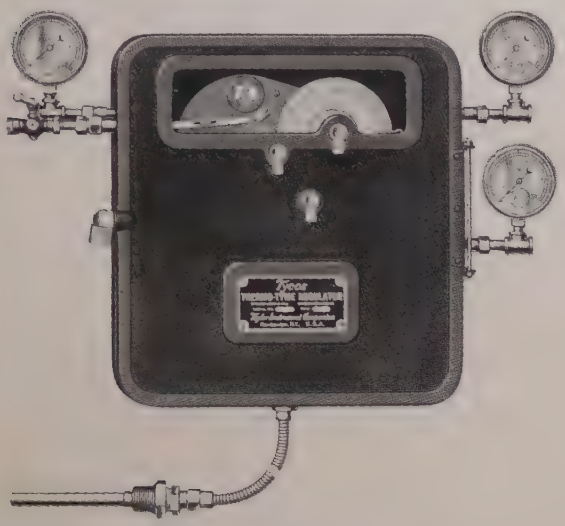


Fig. 47
Single-Duty Capillary-Type Temperature-and-Time Regulator (Air-Operated). For Controlling temperature and time in Batch Stills.

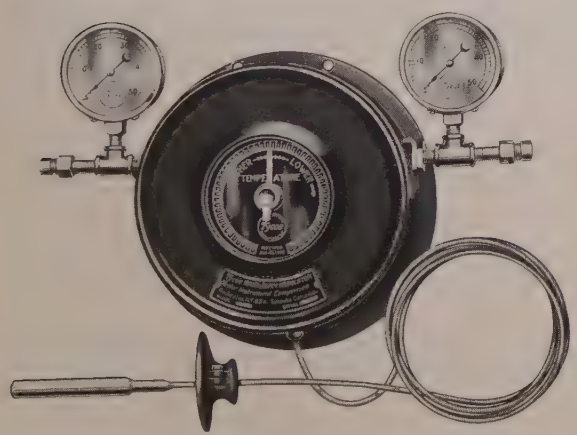


Fig. 48
Single-Duty Mercury-Actuated Capillary-Type Temperature Regulator (Air-Operated). Used for controlling fixed temperatures in Crude-Oil Stills, Solder Baths, etc.

Systems of Automatic Control Applicable to "Fire Distillations"

In the firing of the stills the necessity for the proper maintenance of working temperatures is quite apparent. Oil-or-gas-fired stills using one pipe burner (that is a burner which induces its own air for combustion) can be controlled automatically. In a "batch" still, where a steady temperature rise is maintained, a system of automatic control will regulate temperatures in accordance with a predetermined time and temperature schedule. This is accomplished by use of the Temperature and Time Regulator (*Fig. 47, page 25*) whereby temperature rise is maintained at any uniform or varied rate and the temperature itself is at all times controlled by regulating the fuel supply to the burner through a diaphragm valve in the fuel-supply line. A particularly noteworthy feature of this instrument is the automatic "blow-off", which functions at the end of a predetermined time to terminate the process under control.

Temperature Regulators control fixed temperatures in continuous-type stills. With the sensitive member of the regulator inserted in the still, an undue rise in the temperature of the oil will automatically cause the fuel supply to be throttled down to a more restricted flow. A fall in the temperature of the oil will in like manner admit more fuel to the burner to compensate for the change in condition as reflected at the bulb of the regulator. The Mercury-Actuated Temperature Regulator (*Fig. 48, page 25*) is characterized by sturdiness of construction and sensitivity of operation, making it particularly adaptable to still-temperature control. This instrument will control temperatures to a maximum of 1000° F. and the individual regulator possesses the same degree of sensitivity throughout the entire range of its control. The operation of the Mercury-Actuated Temperature Regulator depends on the movement of a coil, caused by the expansion or contraction of mercury in an air-tight heavy capillary tube system. This movement opens or closes an airport, which controls the compressed air used as the motive power for operating a diaphragm valve in the fuel supply line.

Extra-Heavy Separable Well for Oil-Stills

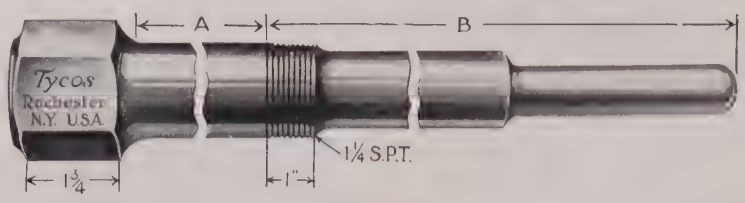


Fig. 49
Extra-Heavy Separable Well for use with Industrial-Type Indicating Thermometers, Recording and Index Thermometers, and Temperature Regulators. Showing Exterior Construction

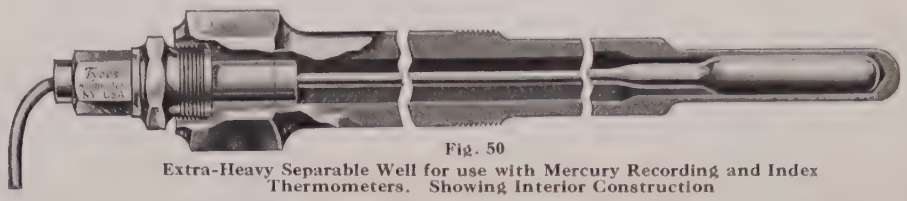


Fig. 50
Extra-Heavy Separable Well for use with Mercury Recording and Index Thermometers. Showing Interior Construction

In applying temperature instruments to oil stills, it is advisable for the following reasons to use a separable well (socket) into which the bulb (sensitive member) fits:

1.—It insures a tight joint through the wall of the still, thus preventing the fire hazard which otherwise would result from oil leakage.

2.—It protects the bulb of the instrument against the severe wearing action of the agitated oil, or against electrolysis which may take place between the shell of the still and the bulb of the instrument.

3.—It permits removing and replacing the instrument during a run.

To meet satisfactorily the unusually severe service, an extra-heavy separable well has been designed, which, thoroughly tried out in a number of large refineries, has met all requirements. It is made in three sections: The wrench-head, machined from heavy bar stock and measuring two inches across the face; the connecting-stem, made from extra-heavy double-thick pipe; and the bulb-chamber, accurately machined from solid stock. Instead of screwing the wrench-head to one end of the stem and the bulb-chamber to the other, both joints are welded, so that the finished well is one homogeneous piece. Screwed joints are dangerous, because the constant heating and cooling will loosen the threads, resulting in leakage.

The construction of this Extra-Heavy Well for use with Industrial-Type Indicating Thermometers, Recording and Index Thermometers, and Temperature Regulators, is the same in each case, except for a variation in the size of the bulb chamber, which of course must be machined to fit accurately the bulb of the particular type of instrument with which it is to be used.

To take care of insulation or brick setting on still heads, provision is made to furnish the well with three different lengths of extension between the wrench-head and top of thread; bringing the wrench-head outside where a wrench can be used easily, and furthermore eliminating the necessity of cutting away the insulation. The standard lengths of extension-neck between wrench-head and thread are 3, 7½ and 12 inches. The standard lengths of stem, measuring below the top of thread, are 12, 18, 24 and 30 inches, which gives sufficient variation to take care of practically all installations. The thread is 1¼-inch S. P. T.

That this well has met with such unqualified approval is not surprising since heretofore the wells for applying temperature-instrument bulbs to oil stills have been rather haphazard arrangements and much trouble and dissatisfaction have resulted from their use. The proper application of the bulb (sensitive member) to the still, so that it will have good heat contact with the oil, is of paramount importance if accurate results are to be obtained. Second in importance is durability. The type of well here described (*illustrated above*) meets the most exacting demands in these respects.

Distillation by Steam

Petroleum distillation is accompanied always by partial decomposition. At the temperatures employed for driving off the lower boiling constituents this factor is relatively small, but it increases with rise in the temperature of distillation. At the higher temperatures necessary to drive off the heavier distillates of the crude at their normal boiling points, the factor of decomposition is prevalent to such an extent as to occasion appreciable distillation loss and to affect vitally the character of the lubricating stocks produced from the distillate itself.

The production of the best grade of lubricants therefore necessitates the recovery of the heavier fractions of the crude at a temperature below their normal boiling points. This is being accomplished to a great extent through distillation by the aid of steam. Through the physical law of vapor-pressure relationship, this operation is equivalent in effect to a lowering of the absolute pressure under which distillation of the crude is carried out.

In the refining to cylinder stock of a paraffin-containing crude, considerable quantities of steam are injected into the still after the gasoline, naphtha, kerosine, and part of the gas-oil have been driven off, and this process continues until the distillation run is completed. The main products from this operation are gas-oil, wax-distillate and steam-refined stock.

Gas-oil being of lighter gravity, distills over first. When the stream of distillate shows a certain gravity, a cut is made and the remainder coming over until the residue in the

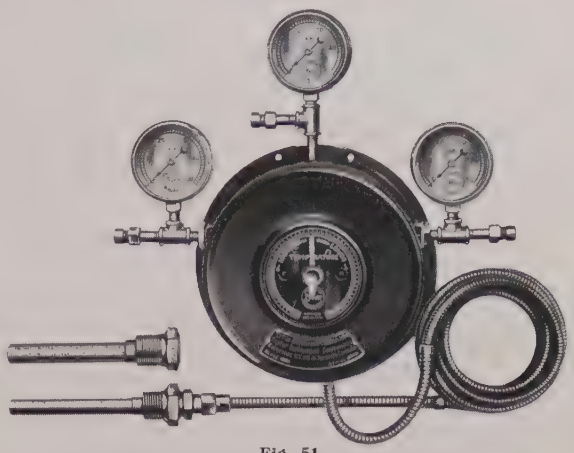


Fig. 51
Double-Duty Unit-System Capillary-Type Temperature Regulator (Air-Operated). Used for controlling temperatures in Steam Stills or Preheaters, where exhaust steam for heating can be supplemented by live steam if needed. Used also for controlling heating and cooling mediums, as in "Blow" Tanks.

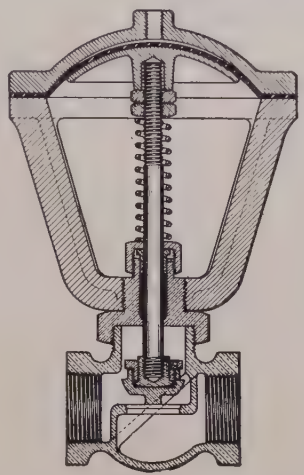


Fig. 52
Direct-Acting Diaphragm Valve

Direct-Acting Diaphragm Valves are so constructed that when the disc is in its normal position (no air pressure on the top) the valve is wide open. The disc seats from the top, so that when air pressure is applied to the diaphragm top the disc moves toward the seat, closing the valve. Just enough air pressure is applied to the diaphragm by the regulator to overcome the resistance due to the spring and the fluid under the disc, so that the valve is held in a throttling position.

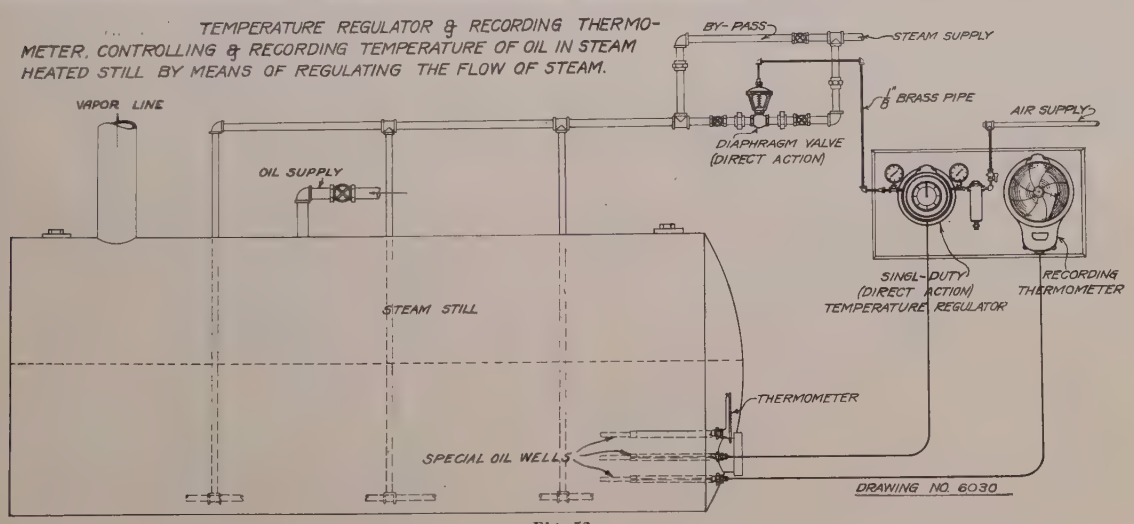


Fig. 53

still shows the desired flash or fire test, may be classed as wax distillate. "Steam-refined stock", or "cylinder stock", is the term applied to the residuum or "bottoms" remaining in the still after the distillation has been completed.

The gas-oil distillate is mixed with the gas-oil from the preceding distillation and is used either as a light fuel oil, or in the manufacture of water gas. It is used also as cracking stock from which the lighter motor fuels, such as gasoline, can be produced. Wax distillate serves as a basis in the manufacture of paraffin wax and lubricating oils, a refinery procedure representing probably the most expensive and diversified operations in the oil-refining industry. From the steam-refined stock, petrolatum and special grades of lubricants are derived.

The term "steam distillation" in its strict sense is more particularly applied to the further refining of the raw gasoline and kerosine cuts previously recovered from the fractional distillation of the crude. Redistillation of the light-oil cuts by the use of steam results in the recovery of more homogeneous products from the standpoint of boiling ranges and gravities than is sometimes possible to accomplish in straight crude distillations. Steam distillations as here applied are carried out in so-called "steam stills." These stills are generally of the horizontal type and are heated by a large number of either perforated or closed steam coils.

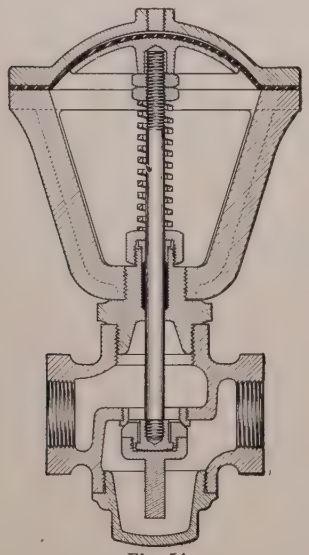


Fig. 54
Reverse-Acting Diaphragm Valve

Reverse-Acting Diaphragm Valves are so constructed that when the disc is in its normal position (no air on top), the valve is closed by a spring. The disc seats from the bottom, so that when the pressure is applied to the diaphragm the disc moves from the seat, opening the valve. The steam, or other substance passing through the valve, enters under the seat, and because of this the valve cannot be throttled but is always full open or completely closed. This type of valve should be used when an "on" or "off" condition is desired, such as the shutting off of the heating or cooling medium in case of air-supply failure.

Systems of Automatic Control Applicable to Steam Stills

The essential requirement in distillations involving the use of steam is a constant source of steam supply necessary for the operation of the still. This generally is supplied from the main steam plant. In some cases live steam direct is used, while in others quantities of exhaust steam from pumps or engines about the plant may be available. A system of the latter kind, however, usually is connected with the main steam supply so as to have an additional source in case the exhaust supply is insufficient.

When the temperature of the oil in stills is dependent on the live-steam supply, fixed temperatures are maintained by the use of the Capillary-Type Temperature Regulator (*Fig. 48, page 25*). This automatically controls the temperature of the still by regulating the steam by means of a diaphragm valve inserted in the main steam-supply line. A typical application of this control is shown (*Fig. 53, page 27*).

In processes using exhaust steam supplemented by live steam, still temperatures are controlled by means of the Double-Duty Unit-System Temperature Regulator (*Fig. 51, page 27*). This regulator connected to two diaphragm valves, one in the exhaust-steam line and the other in the live-steam line, permits the necessary amount of exhaust steam to be used and when heat from this source becomes insufficient, automatically opens the live-steam line until the desired temperature has been reached.

Industrial Thermometers (*Fig. 39, page 21*) Recording Thermometers (*Fig. 18, page 10*) and Index Thermometers (*Fig. 30, page 17*) are used extensively in steam-distillation practices for indicating and recording temperatures both in the stills and vapor lines.

The Expansion-Stem-Type Temperature Regulator (*Fig. 22, page 14*), is widely used for controlling temperatures in steam stills where steam from one source only is used as a heating medium.

Distillation Under Vacuum

In the recovery of the various fractions from the crude, decomposition, with its consequent destruction of valuable products, is prevented through distillation under vacuum. This procedure is a direct lowering of the boiling points and removal of the vapors at reduced temperatures. In the refining of a paraffin-containing crude, it is customary practice with some refiners using vacuum to separate the lighter products in the regular conventional-type stills and then transfer the residue to vacuum stills for the removal of the wax-distillate cut.

Vacuum distillation processes are of two general types; the wet vacuum system, where steam is being injected into the oil during the distillation process, and the dry system with its high vacuums.

Vacuum stills are of the same general arrangement as fire stills but are characterized by heavier construction and supports, as a safeguard against danger of possible collapse.

Fig. 55

Mercury-Column Absolute-Pressure Gauge, for applications in connection with distillations under vacuum. Furnishes a direct reading of the actual pressure existing in an apparatus under vacuum. The indications are independent of barometric pressure or changes of level of mercury in the cistern, both of which factors must be considered when taking a reading with a mercury-column vacuum gauge.

Instruments Applicable to Vacuum Distillation Processes

The Absolute-Pressure Gauge (*Fig. 55, page 29*) gives a direct reading of the actual pressure existing in vacuum stills and finds extensive use for this application in the refining industry. This instrument is furnished in convenient size, mounted on hardwood panel adaptable to permanent installation. The scale is 12 inches long, graduated 0 to 11 inches in one-tenth inch divisions, and also 0 to 5 pounds in ¼-pound divisions. The indications are independent of barometric pressure or changes in the level of the mercury in the cistern. On the panel with the Absolute-Pressure Gauge is mounted a catch-all, which prevents any accumulation of moisture or foreign substance on top of the mercury in the cistern.

The Recording Vacuum Gauge (*Fig. 19, page 11*) will show a continuous record of vacuums existing in vacuum-distillation processes, and is available in a standard range from 0 to 30 inches mercury vacuum with ½-inch chart divisions. This instrument is available also in the bi-record type for showing two records on a single chart.

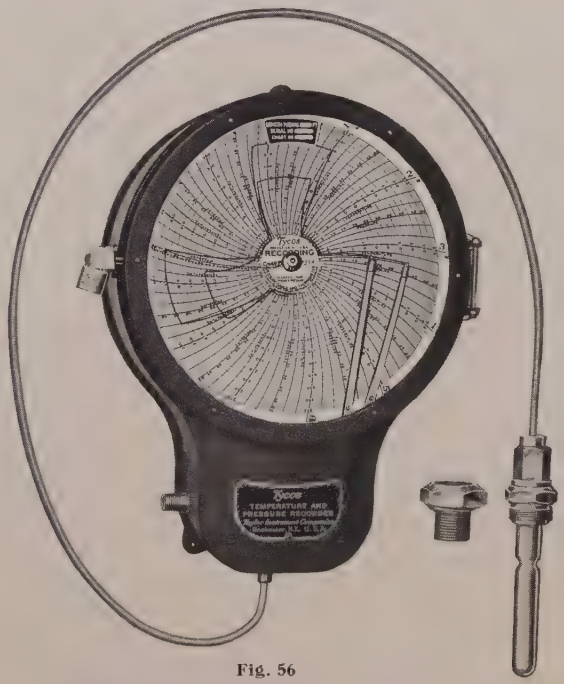


Fig. 56

Combined Recording Thermometer and Pressure (or Vacuum) Gauge. For use wherever temperature and pressure (or vacuum) are related.

Pressure Distillation, or Cracking Processes

Coincident with the expansion of the automobile industry and the corresponding increase in the consumption of motor fuels, a refining practice has been developed whereby the heavier petroleum products of higher boiling points can be converted into the more desirable volatile products which find a readier and wider range of commercial application. This process is known as "cracking", which is commonly referred to as "pressure distillation". The principles of "cracking" usually involve distilling under pressures above atmospheric. This results in a decomposition of the heavier oils, with the resultant formation of a large percentage of products of low gravity and boiling points. The relative importance of this phase of refining can be understood readily when it is considered that about 30 per cent of the gasoline manufactured today is produced by various cracking processes. Some cracking processes require gas oil or similar middle distillates as the raw material; others handle heavy crude, or the entire residues after the gasoline, naphthas and kerosine have been driven off, as in "skimming" or "topping" plant practices.

Decomposition of heavier oils results in the formation not only of the lighter hydro-carbons, but also of products of less commercial desirability and importance. This is evidenced by the formation of uncondensed gases and in the accumulation of coke and tarry products in pressure stills. Ordinarily the gases so produced can be collected and utilized as a source of heat. The excessive deposition of carbon is highly undesirable, not only from the standpoint of fuel conservation but also on account of the attendant dangers from its accumulation. The necessity for the constant removal of this bi-product limits the period of the cracking operation.

In cracking processes the distillation is carried out under the pressure of the oil's own vapor. This is accomplished by first getting the distillation under way normally and then closing valves until the pressure has built up to the desired point. In some cases pressures are maintained only in the still; in others both distillation and condensation of vapors are carried out under pressure. In the latter the pressures on the condensing unit, or receiver house are in many cases considerably lower than in the still, this lowering being brought about through a manually-operated control valve between the distillation unit and the condenser. The pressure on the liquid in the distillate receiving house is produced by the dry

Instruments Applicable to Cracking Processes

The various types of Indicating and Recording Thermometers, Recording Pressure Gauges, Indicating and Recording Pyrometers, and Temperature and Pressure Regulators are applicable to various cracking process requirements.

STEAM PRESSURE CONTROL

The maintenance of uniform steam pressure is of primary importance in the successful operation of refinery cracking units. The Air-Operated Pressure Regulator (*Fig. 62, page 35*) in conjunction with a Diaphragm Valve (*Fig. 23, page 14*) will automatically effect such a regulation to a closeness of control practically unattainable by any other type of instrument.

TOWER TEMPERATURE CONTROL

The importance of tower temperature control and various methods of effecting such control are taken up under the heading "Automatic Control for Fractionating or Bubble Towers" (*page 39*).

BACK-PRESSURE CONTROL

In the operation of cracking units or pressure stills, when condensation is carried out under pressure the liquid and uncondensed gases are separated in receiving tanks, or separators. In such cases it is generally desirable to maintain a constant pressure on the unit as an aid in insuring equilibrium of process operation. The Reverse-Acting Pressure Regulator (*Fig. 62, page 35*) in conjunction with a Direct-Acting Diaphragm Valve in the gas-discharge line from the separator will automatically maintain constant back pressure on the unit to a remarkably close degree. This regulator acts as a pressure relief valve and the action of the control valve is instantaneously responsive to the slightest change of pressure in the system, above the point for which the regulator is set.

In some cases where these controls are used on the above applications, it is possible to use the dry gas itself, properly reduced in pressure, to operate the regulator.

gases which were not liquified in the passage of the still vapors through the condenser.

Cracking processes may be divided into two general classes: (1) Vapor-phase cracking, (2) Liquid-phase cracking. Cracking in the vapor phase consists in vaporizing the oil and then producing the reaction by the application of additional heat, or of heat and pressure together, to the vapor. In liquid-phase cracking in general, heat and pressure are applied to the oil while in the liquid form, with some part of the liquid in contact with the vapor.

The most widely used cracking processes in the refining industry are of the liquid-phase type. Some of the more prominent of these are:—

The Cross Process

The Dubbs Process

The Jenkins Process

Fig. 57
Recording Pyrometer
Used for Recording Oil-Still Furnace Temperatures, etc.

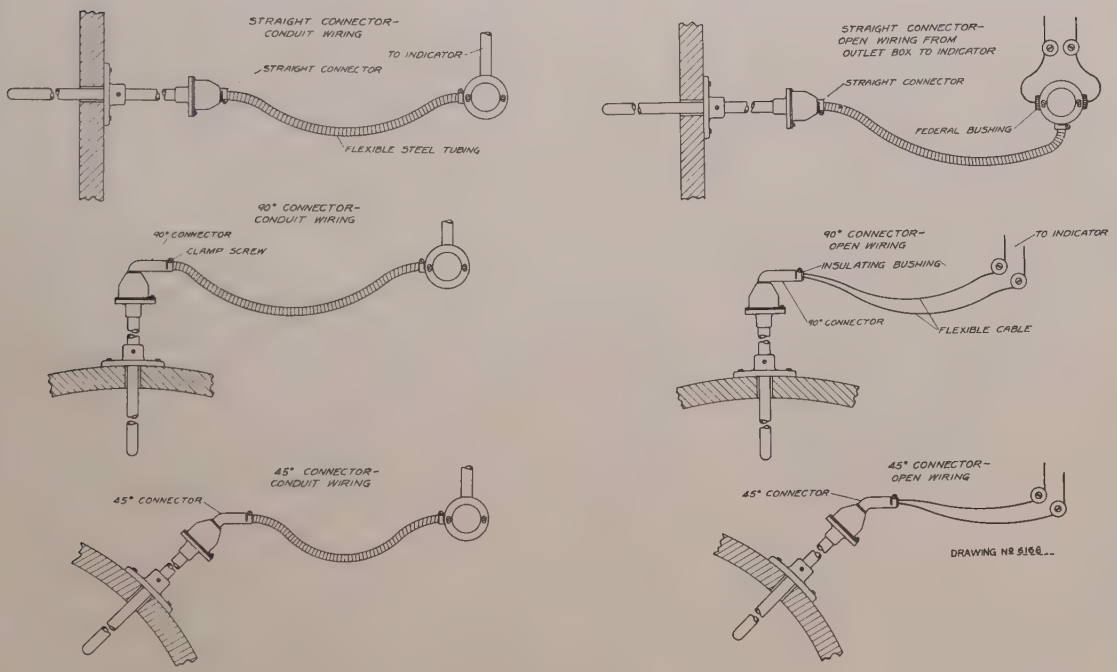


Fig. 58
Methods of Installation of Thermocouples as Applied to Conduit Wiring or Open Wiring

The Cross-Cracking Process

In the Cross Process, actual cracking of the oil is accomplished at high temperatures and pressures with the oil still in the liquid state. Subsequent vaporization, or distillation, is effected under greatly reduced pressures by the heat remaining in the oil after the cracking reaction.

A Cross unit consists of an upper and a lower series of heating coils arranged in a furnace, a reaction chamber, a vaporizer (evaporator tower), a heat exchanger and fractionating or bubble tower, the necessary condensing units, and a gas separator.

In the operation of this process, the incoming oil, or charging stock, is forced into the system by means of a high-pressure pump. It passes first through the heat-exchange coils in the top of the fractionating tower, where its temperature is raised to about 300°F. through contact with the hot vapors. From here the oil enters the upper or preheating coils of the furnace, and the heat from the flue gases coming in contact with this series of coils is sufficient to raise its temperature to approximately 550°F. Passing next through the lower series of heating coils, the oil enters the reaction chamber at a temperature between 850° and 900°F. At this point its velocity is reduced, and actual cracking takes place. An operating pressure of 500 to 700 pounds is maintained throughout the system, to keep the oil in the liquid state at the high operating temperatures.

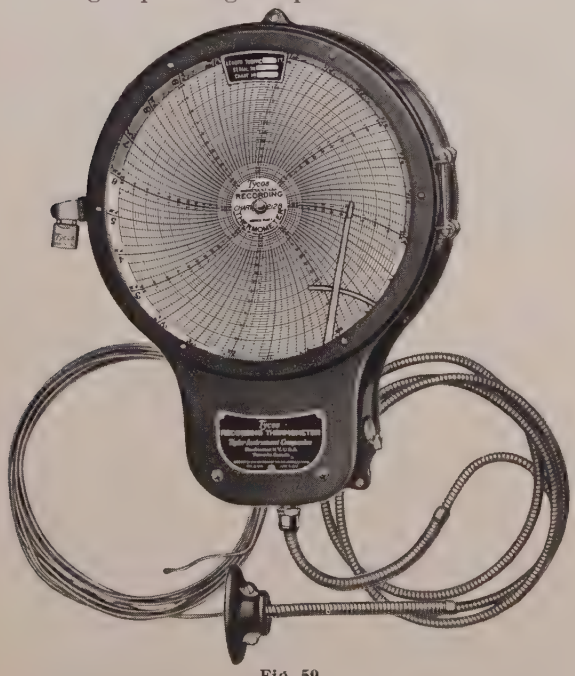


Fig. 59
Recording Thermometer with Capillary Bulb and Clamp Flange

Instruments Applicable to the Cross Cracking Process

FURNACE

In a Cross Unit, the Recording Pyrometer (*Fig. 57, page 31*) is applicable in a standard range to 1800°F., for furnishing a continuous record of the coil-furnace temperatures. This instrument is furnished also in the duplex recording type, (*Fig. 42, page 23*) to show two records on a single chart.

Indicating Pyrometers (*Fig. 26, page 16*) are similarly applicable for showing temperatures within a like range. The Indicating Pyrometer is furnished with a Steel Switch-Box Panel to take care of two or four installations, or with a Rotary Switch (*Fig. 27, page 16*) standard for either six or twelve thermocouple installations.

FLUE

The Recording Thermometer (*Fig. 18, page 10*) is applicable in a standard range from 200 to 1000°F., for recording "flue" temperatures. For this type of application the thermometer has a capillary bulb (*similar to Fig. 59, page 32*) approximately 30 feet long, exposing a large surface to the heat medium. It is sensitive therefore to slight and rapid changes in temperature, and because of its extended length enables an average temperature condition to be recorded.

OIL AND EVAPORATOR TOWER

Recording Thermometers (*Fig. 18, page 10*) are applicable in standard ranges of 200 to 1000°F. and 550 to 950°F., for recording temperatures of the oil from the furnace to the reaction chamber, and also temperatures in the evaporator. The Bi-Record Recording Thermometer (*Fig. 45, page 24*) will show on a single chart records of temperatures at two different points.

The Index Thermometer (*Fig. 108, page 59*) is applicable for indicating clearly and accurately the temperature of the oil from the furnace to the reaction chamber.

REACTION CHAMBER

The Recording Pressure Gauge (*Fig. 19, page 11*) will show a continuous record of pressures existing in the reaction chamber.

The cracking of the oil in the reaction chamber results in the formation of "synthetic crude". After the expiration of a definite reaction period it is admitted through a manually-operated valve into the vaporizer, with a reduction of pressure to about forty pounds. This pressure drop and free expansion result in immediate vaporization of the lighter portions of the oil, the heavier ends collecting in the bottom of the chamber from which they are drawn off as fuel oil. The vapors and fixed gases pass from the top of the vaporizer into the bottom of the fractionating or "bubble tower". Through a process of partial condensation the lighter vapors are here separated from the higher boiling components, the latter falling to the bottom of the tower to be withdrawn as recharging stock for the still. A reboiler is provided in the base of the fractionater, which reboils the tower bottoms and drives off any remaining light products. Heating of the reboiler is accomplished by by-passing through it part of the cracked oil previous to its entrance to the vaporizer.

The lighter vapors in the upper part of the tower are subjected to a further cooling by their passing over the charging-stock heating coil. Subsequent contact with a small oil-or water-cooled coil determines the temperature at which the vapors leave the tower and this factor is controlled by regulating the flow of the cooling medium through this coil.

The vapors from the fractionating tower, comprising the gasoline and uncondensable gases, pass through the water-cooled final condensers into the receiving tank or gas separator. The gasoline is withdrawn to storage, while fixed gases are used as furnace fuel.

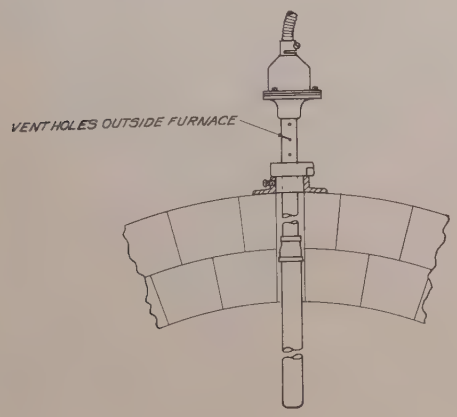


Fig. 60

Standard Base-Metal Thermocouple as installed in crown of Annealing Furnaces, Lehrs, Kilns, Flues, etc. with or without metal or refractory secondary protection tubes, as required by the application.

STEAM LINE

The Recording Pressure Gauge (*Fig. 19, page 11*) is applicable also for recording pressures in the steam line.

GAS SEPARATOR

In a Cross unit, the Reverse-Acting Pressure Regulator (*Fig. 62, page 35*) is applicable for maintaining a constant back pressure on the gas separator. This regulator will serve to release excess gas and its action is immediately responsive to the slightest change in pressure above that for which the instrument is set.

STEAM PRESSURE

The Direct-Acting Pressure Regulator (*Fig. 62, page 35*) will act as a steam reducer to maintain constant pressures for operating a Cross unit.

FRACTIONATING OR BUBBLE TOWER

The Recording Thermometer (*Fig. 18, page 10*) is applicable for recording temperatures in the outlet vapor line from the fractionating or bubble tower.

The system of automatic control is applicable in the Cross process for regulating temperatures in the outlet vapor line from the bubble tower. A complete description and application of this system is given separately under the head of Automatic Control for Fractionating or Bubble Towers (*Page 39*).

Where it is particularly desirable to locate all indicating and recording instruments at a central point, the Distance-Reading Electric Transmitting Recording Thermometer and Pressure Gauge (*Fig. 46, page 24*) is applicable. This type of instrument will record temperatures and pressures at distances of several thousand feet from the apparatus where these conditions are measured.

The Distance-Reading Electric Transmitting Recording Thermometer is essentially a recording thermometer possessing the advantages of a pyrometer from the standpoint of remote temperature measurement, without the accompanying delicacy of construction and operation that exists to some extent in any type of galvanometer instrument.

The Dubbs Process

The Dubbs Cracking Process consists essentially of a two-compartment furnace, in one of which is housed a continuous coil heated by the fires from the adjacent compartment, an expansion chamber connected to the heating coil, a vapor line connected from the top of the expansion chamber to the bottom of a "dephlegmator" or partial condenser, a water-cooled condenser connected to the dephlegmator, and a pressure-distillate receiver.

In operation, the raw oil is pumped to the heating coils, either directly or through the dephlegmator where its cooling effect tends to condense the heavier vapors from the still. The hot oil is discharged from the heating coils into the expansion or reaction chamber, at temperatures usually around 840°F. and under a pressure of approximately 120 pounds where vaporization of the liquid takes place. The heavier portions, or the residual oils, pass out from the bottom of the chamber to storage, and the cracked vapor passes to the dephlegmator. The heavier fractions here condensed are returned to the still; the lighter vapors and uncondensable gases pass through the water condenser to the pressure-distillate receiver, from which the condensate flows continuously through a control valve to a storage tank. The uncondensed gas in excess of that required to maintain constant pressure on the system is vented and burned in a furnace.

The temperature of the outlet vapors from the dephlegmator may be controlled by pumping back into the top of the dephlegmator part of the cool cracked distillate, the quantity of such distillate determining the final outlet temperatures of the vapors.

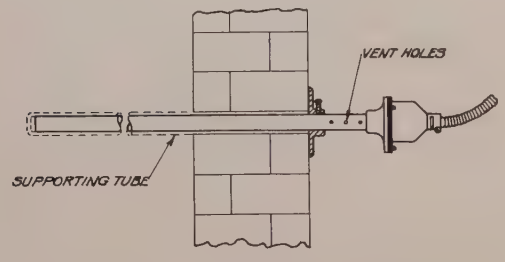


Fig. 61

Standard Base-Metal Thermocouple on back or side of furnace when not under pressure. Extension over 18" inside furnace wall requires extra supporting tube if temperature is high.

Instruments Applicable to the Dubbs Process

In this process the proper admission of the cooling medium is essential to the close and accurate control of the temperature of the vapors leaving the dephlegmator. In this connection attention is called to the System of Automatic Control which will be found outlined under the head of "Fractionating or Bubble Towers" (*page 39*).

Recording Thermometers (*Fig. 18, page 10*) are applicable in the Dubbs Process for showing continuous records of the combined feed and residuum temperatures, the temperature of the oil leaving the heating coil to the expansion chamber and of the vapors leaving the dephlegmator. Bi-Record Recording Thermometers (*Fig. 45, page 24*) will show on a single chart a continuous record of the temperatures of the combined feed and of the oil leaving the heating coil.

Recording Pyrometers (*Fig. 57, page 31*) are recommended for furnace applications. They are furnished also in the duplex type (*Fig. 42, page 23*) for recording temperatures at two different points, or for furnishing check temperatures at two similar points in the furnace. Recording Pyrometers indicate as well as record temperatures.

Where several units of the Dubbs Process are employed the Indicating Pyrometer (*Fig. 26, page 16*) in connection with the Twelve-Point Double-Pole Rotary Switch (*Fig. 28, page 16*) will show temperatures at two different points on as many as six furnaces. The Double-Pole Rotary Switch is furnished also standard for six points.

In all operations where temperatures are a factor Recording Thermometers (*Fig. 18, page 10*) are applicable for all installations where operating temperatures are below 1000°F.

Recording Pressure Gauges (*Fig. 19, page 11*) are applicable in the Dubbs Process for installation on the pressure-distillate receiving tank, pump lines, or elsewhere in the system, for showing a continuous record of operating pressures.

The critical points in the Dubbs Process as set forth in a description by the Universal Oil Products Co., are:

"(1) The transfer temperature; i.e. the temperature of the oil leaving the heating coil to the expansion chamber. This temperature averages about 840°F., varying with the oil treated. (2) The temperature of the vapors leaving the dephlegmator. This is controlled as stated previously by recirculating a predetermined quantity of pressure distillate entering near the top of the dephlegmator. An alternative method is to pass the raw feed through the dephlegmator, or split the feed. This temperature would average about 540°F., varying with the type of distillate desired. (3) The pressure; controlled by a needle valve. Excess uncondensable gas is returned to the furnace to be burned as fuel. (4) Pressure distillate draw off . . . "

"Temperature-recording instruments and pressure gauges are provided for all the above factors. In addition instruments are provided also for recording the furnace, combined feed and residuum temperatures . . . "

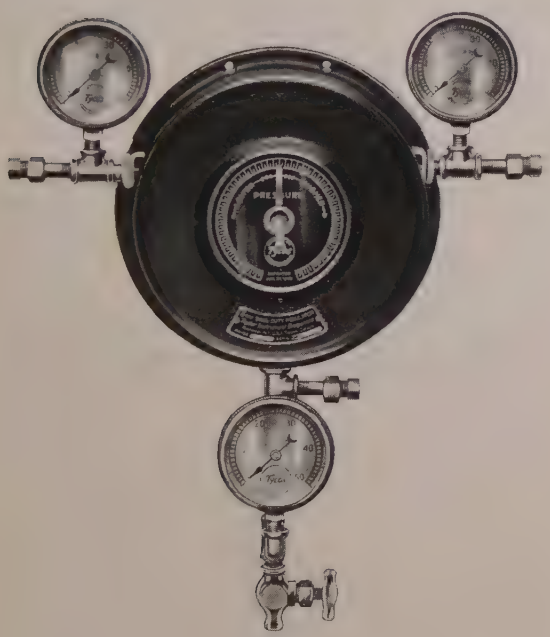


Fig. 62
Pressure Regulator (Air or Gas-Operated)

Distance-Reading Electric Transmitting Recording Thermometers and Pressure Gauges (*Fig. 46, page 24*) are recommended for recording temperatures and pressures at distances of several thousand feet from the apparatus where these conditions are measured.

BACK PRESSURE CONTROL

The Reverse-Acting Pressure Regulator (*Fig. 62, page 35*) is applicable on a Dubbs unit for automatically maintaining a constant pressure in the pressure-distillate receiving tank. This instrument, acting as a pressure relief valve, in conjunction with a diaphragm valve in the gas discharge line will serve to release instantaneously any excess gas pressure above that desired in the system, and for which the regulator is set.

In the above application of this controller it is possible to use the dry gas from the separator for operating the regulator.

STEAM PRESSURE CONTROL

The maintenance of constant steam pressure is of essential importance in the successful operation of the Dubbs unit. Irregular steam pressures are reflected in irregular speeds of the various pumps, resulting in irregular charge of feed, temperatures in the dephlegmator, pressures in the unit, and furnace temperatures where steam is being used to atomize the fuel.

The Direct-Acting Pressure Regulator (*Fig. 62, page 35*) in conjunction with a Direct-Acting Diaphragm Valve (*Fig. 52, page 27*) will act as a steam reducer, to automatically maintain constant pressures for operating the Dubbs unit.

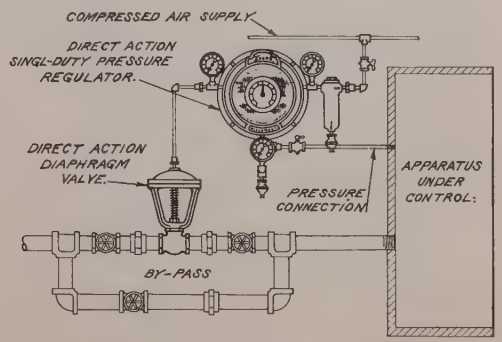


Fig. 63
Method of Installing Pressure Regulator and Diaphragm Valve

The Jenkins Process

A Jenkins cracking unit consists of a specially-designed still and furnace, with a reflux tower and bubble tower of standard construction.

The still, as described in a bulletin furnished by the Graver Corporation, consists of a horizontal steel drum located above the furnace. This drum is connected near each end by downcomers, or sluiceways, to two cross drums located at right angles to the upper drum, the rear sluiceway being longer than the one at the front. These cross drums are connected by inclined tubes, as in standard water-tube boiler construction. The tubes pass through the furnace of the still, the rest of the apparatus being located entirely outside the heating zone. A horizontal propeller is located near the upper part of the rear sluiceway.

In operation, the charging stock is pumped into the top of the reflux tower where it is preheated by the vapors from the still. From here it enters the still, immediately above the propeller. The heavier vapors condensed in the tower are fed into the still by gravity. The entire charge of oil is continuously circulated at a high velocity through the heating tubes and the still drums, by the propeller. The oil is cracked during passage through the tubes. The vapors separated from the oil pass from the upper drum through a goose-neck pipe into the reflux tower.

Still temperatures in the Jenkins Process are usually around 750°F. under an operating pressure of approximately 135 pounds. A pressure relief valve is provided between the reflux and the bubble tower, to maintain the desired pressure in the still and reflux equipment.

The vapors from the reflux tower pass to the bubble tower, where further fractionation takes place. The lighter gasoline vapors emerge from the top of the bubble tower to the final water-cooled condensers. The fractions condensed in the tower issue from the bottom as a pressure distillate. This product is redistilled, giving a gasoline and gas oil, the latter being recycled through the still.

The Jenkins Process comprises additional units, which allow continuous carbon removal from the still. Oil is constantly drawn from the bottom of the front cross-drum into an expansion chamber, where through reduced pressure vaporization of the lighter oil components takes place. The vapors from this stage pass into a standard condenser and then run to storage as recycle stock to be charged into the system again. The residuum

Instruments Applicable to the Jenkins Process

In a Jenkins unit, instruments are important for recording temperatures at two points in the furnace, for indicating the temperatures in the still, bubble towers, and stack gases, for recording and controlling temperatures in the reflux and bubble towers and for recording operating pressures at any desired point in the system.

Index Thermometers (*Fig. 108, page 59*) and Recording Thermometers (*Fig. 18, page 10*) are particularly applicable in the Jenkins Process for indicating and recording temperatures in the still, the outlet vapor line from the towers, bottom of bubble towers, and of the stack gases where these temperatures are below 1000°F.

The Distance-Reading Electric-Transmitting Recording Thermometer is applicable (*Fig. 46, page 24*) for recording temperatures at a distance of several thousand feet from the point where this condition is measured.

In a Jenkins unit, the Duplex Recording Pyrometer (*Fig. 42, page 23*) is applicable for recording temperatures at two different points in the furnace. This instrument has two independent galvanometers, can be furnished with an electric clock for alternating currents at 110 or 220 volts, and both indicates and records temperatures at standard ranges of 0 to 1200°F., 0 to 1800°F., or 0 to 2400°F.

Pyrometers are similarly applicable for indicating or recording temperatures in the still, in the bottom of the bubble towers, and of the stack gases. By use of the Rotary Switch (*Fig. 27, page 16*) temperatures at as many as twelve points can be taken on a single Indicating Pyrometer (*Fig. 26, page 16*). The Six-Point Double-Pole Rotary Switch is furnished also standard for six different points. The rotary switch and indicator can be mounted on a hardwood panel-board, together with a selective switching device. A Metal Protection Case (*Fig. 65, page 37*) is available to cover any standard panel board, thus protecting both panel-board and instrument and consequently lengthening the life of the installation. Hardwood Protection Cases (*Fig. 43, page 23*) are provided for Indicating Pyrometers.

from the expansion chamber is conveyed to a settling tank, where the carbon which has hitherto been held in the amorphous form through the addition of a small amount of hydrated lime to the charging stock, settles out of the oil and is withdrawn. The oil itself is transferred to storage as fuel oil.

In later modifications of the Jenkins Process, two bubble towers are used. In original units the high-gravity gasoline is taken from the top of the bubble tower and the condensate from the bottom of this tower is subjected to a redistillation. Instead of making this rerun as a separate operation, it is accomplished through the application of the reboiler, in which the vapors comprising the recycle stock emerging from the expansion chamber previously described are employed to furnish the necessary heat for the distillation. The vapors from this distillation pass to a second bubble tower, gasoline vapors emerging from the top, while the tower condensate is fed back to the reboiler for further processing with the condensate from the first bubble tower. The stream from the reboiler, consisting of gas-oil and pressure distillate, is used as recycle stock.

In a Jenkins unit, temperatures in the outlet line from the reflux tower are regulated by the flow of the charging stock to the tower.

Temperatures in the outlet vapor lines from the bubble towers, which determine the end point of the gasoline produced, are regulated by spraying in cold oil or circulating it through coils in the top of the towers.

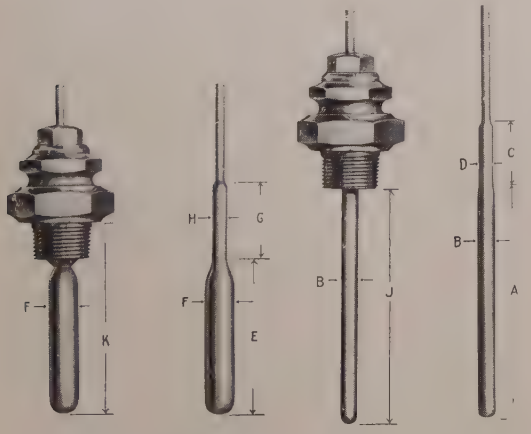


Fig. 64
Bulbs for Mercury-Actuated Recording and Index Thermometers

The Recording Pressure Gauge (*Fig. 19, page 11*) with a standard chart graduated from 0 to 150 pounds in two-pound divisions, will furnish an accurate and continuous record of operating pressure at any point in a Jenkins unit.

In the Jenkins Process, the temperature of the vapors leaving the towers can be regulated by the system of automatic control which is taken up and described on page 39 under the head of "Automatic Control for Fractionating or Bubble Towers".

BACK-PRESSURE CONTROL

The Reverse-Acting Pressure Regulator (*Fig. 62, page 35*) is applicable as a pressure relief-valve, to maintain constant back-pressure in a Jenkins unit. This instrument in conjunction with a diaphragm valve will instantaneously release from the system any gas pressure in excess of that for which the instrument is set.

STEAM-PRESSURE CONTROL

The Direct-Acting Pressure Regulator (*Fig. 62, page 35*) will automatically maintain constant steam pressures and thus aid in securing smooth and regular operation of a Jenkins unit.

Fig. 65
Pyrometer with Rotary Switch, in Metal Protection Case

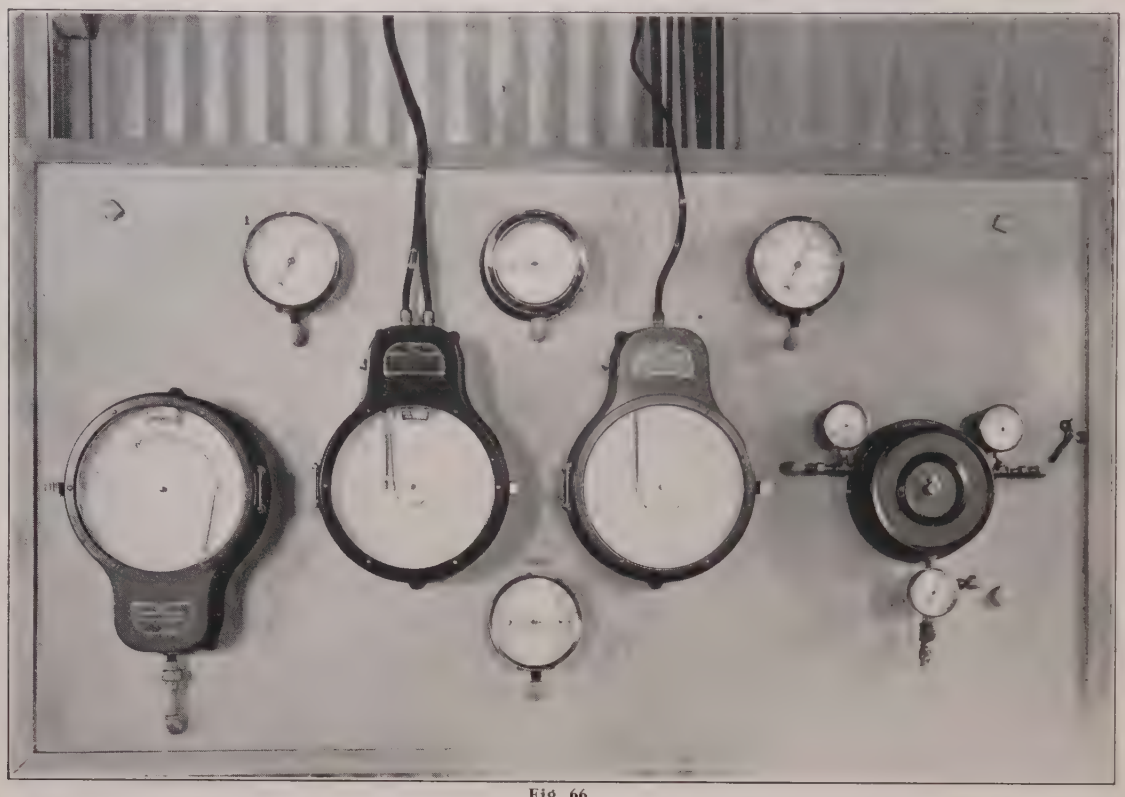


Fig. 66
Instruments used in Connection with the Recovery of Uncondensed Gasoline Vapors from Cracking Units

The panel board shows a Pressure Regulator controlling pressures in accumulator tank and a Recording Pressure Gauge recording the pressure as maintained by the regulator. The Single-Record Recording Thermometer is recording temperatures in residue line from re-boiler. The Bi-Record Recording Thermometer is recording temperatures in compressor discharge line and in fractionating tower.

The small picture shows the Diaphragm Valve working in conjunction with the Pressure Regulator, controlling pressure in accumulator tank.

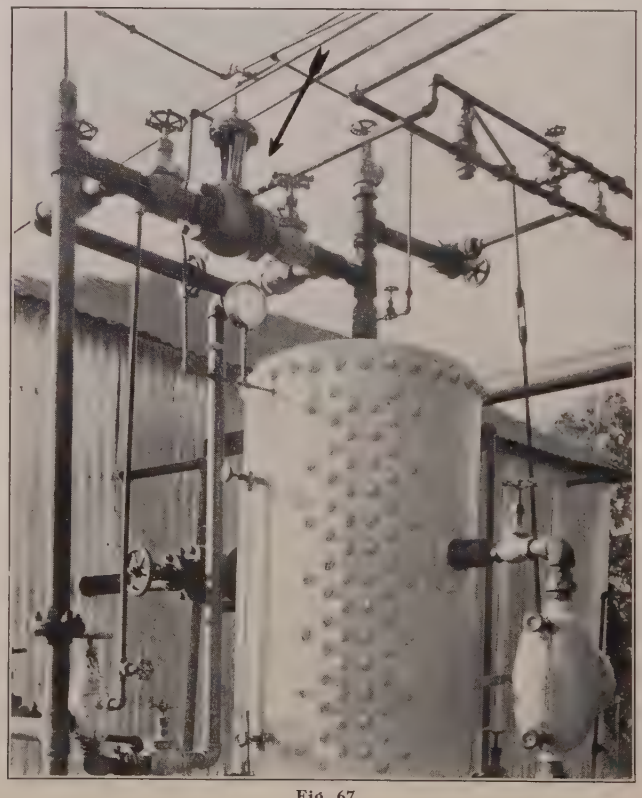


Fig. 67

Fractionating Towers

Of equal importance with the complete recovery of the more volatile petroleum products is their further separation into more homogeneous cuts of comparatively narrow boiling ranges. This could be accomplished through a very slow distillation of the crude, wherein the temperature would be raised at such a slow rate as to permit the individual fractions to be driven off, condensed, and separately collected before the next fraction begins to volatilize. In commercial practices however this procedure would be an economic impossibility, owing to the enormous volume of crude being handled by the average refinery and the time consumption necessary to effect the maximum separation of the various constituents.

In crude-oil distillations it is often necessary to subject the lighter recovered fractions to redistillation, with close process control, in order to secure entirely uniform cuts of standard specifications. Redistillations however have been eliminated to a great extent and closer and entirely homogeneous products have been recovered from the crude through a system of separation during the process of cooling the vapors. This process is one of fractional condensation, and is accomplished by the passage of the vapors through a fractionating column. The term "tower", or dephlegmator, is generally used to describe fractionating apparatus of the above type.

Fractionating towers usually are constructed in such design and dimensions as to offer maximum contact resistance to the passage of vapors and thus to aid the condensation or separation of the heavier or higher boiling constituents. Tower construction may consist of a series of perforated pans at fixed distances apart, or packing with layers of stoneware, hollow tile, wooden grids, coke, steel cuttings, etc., through or around which the rising vapors pass. Tower packing may also be of the ring type, consisting of small metal cylinders of equal diameter and length.

The heavier vapors condensing and collecting in the bottom of the fractionating towers may be either withdrawn or allowed to run back into the still for further processing. The lighter and more volatile constituents leaving at the top may be immediately passed to the water-cooled condensers, or may be subjected to a further process of fractionating.

Automatic Control for Fractionating or Bubble Towers

Since fluctuations in the temperature of the vapors leaving the tower are reflected in the quality and yield of the gasoline produced, the necessity of maintaining a constant temperature in the outlet vapor-line is apparent. Temperature Regulators are essential to efficient operation of fractionating or bubble towers. The most experienced operator can compensate for variations in temperature only after such changes are indicated on a thermometer. Temperature Regulators on the other hand anticipate, as it were, changing temperatures, and compensate for them automatically.

It would be impracticable here to outline other than in a general way a system for automatically controlling tower temperatures. Many cases present individual problems, which consequently necessitate specialized methods of control. Each installation is made in the light of its adaptability to the particular process and method of cooling, and on the basis of successful previous experience.

Automatic Control for Fractionating or Bubble Towers is extensively and successfully used throughout the refining industry.

Where final tower cooling is accomplished by the circulation of cool oil or water under constant pressure through a coil in the top of the tower, automatic control is effected by means of a Reverse-Acting Temperature Regulator (*Fig. 69, page 41*) in connection with a Direct-Acting Diaphragm Valve (*Fig. 52, page 27*) in the cooling line. The diaphragm valve is located as near the tower as is practicable. The sensitive bulb of the regulator is inserted in the throat of the outlet vapor line and the admission of the cooling medium is regulated in accordance with the temperature at this point. The above system is applied likewise where a part of the cold distillate itself, under constant pressure, is pumped back and discharged into the top of the tower, to effect the desired cooling. When the flow of this medium is actuated by an auxiliary steam pump, constant pressure is maintained in the cooling line, up to the diaphragm valve, by the application of a Pressure Regulator (*Fig.*

BUBBLE TOWERS

A certain modification of the fractionating tower which seems to be coming into wider use is known as the bubble tower. This is a type of apparatus which has been used for some time in the fractionating of volatile liquids such as alcohol, ammonia, etc. It consists essentially of a vertical tower or cylindrical drum, in which are a number of plates or trays at certain distances apart. Each tray has a number of perforations in which are located small nipples covered with ferreted or slotted caps. In each tray also is an overflow pipe extending from the level of the top of the nipples down to the plate, or tray, directly underneath and lower than the level of the top of the nipples of the lower plate.

Partial condensation of the still vapors results in the accumulation of an oil layer on each tray, to the level of the overflow pipe. Tower temperatures are successively lower towards the top and the condensate collected at each point may vary correspondingly in gravity and boiling range.

62, page 35) in conjunction with a diaphragm valve in the steam supply line to the pump. This controller regulates the speed of the pump by the proper admission of steam in accordance with the pressure in the cooling-medium supply line.

A System of Automatic Control for bubble towers is shown (*Fig. 68, page 40*) where the cooling medium is under constant pressure; (*Fig. 119, page 65*) shows the additional feature of the pressure regulator when the flow of the medium is actuated by an auxiliary pump.

In some cooling systems where the cold charging stock itself is pumped through a coil in the top of the tower, the need for a constant flow makes it necessary to by-pass the cooling coil in the tower, to allow the desired amount of feed to continue in its course even when the cooling supply to the tower is cut off. Automatic control of tower temperatures is here accomplished by a Double-Duty

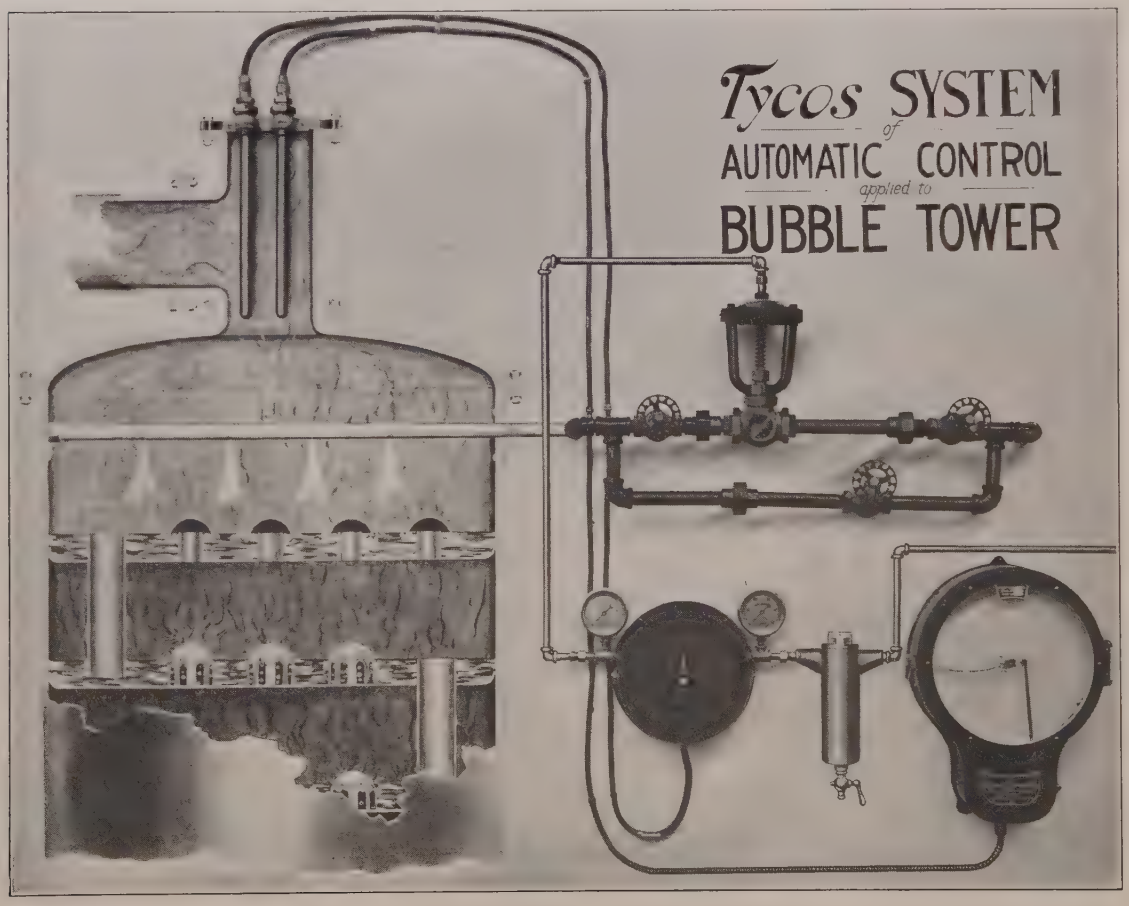


Fig. 68

The hot vapors entering the bubble tower at the bottom pass through the slotted caps and then percolate (bubble) through the oil layers on each tray. This results in a continuous partial condensation of the heavier vapors, with a revaporization of the lighter products which might have hitherto collected in the series of trays.

The heavier distillates which accumulate in the bottom of the tower are usually known as reflux. This is allowed to drain back into the still for reprocessing. The lighter vapors on leaving the top tray undergo a final cooling before they pass from the top of the tower to the water-cooled condensers, to be condensed as gasoline. This cooling may be accomplished either by the proper circulation of part of the cold charging stock through a coil constructed in the top of the tower, or a similarly-constructed water-cooled coil. In some systems part of the cold distillate, or condensed vapor, is itself pumped from the receiving tank and discharged as spray into the top of the tower, the quantity and temperature of such distillate determining the outlet temperature of the vapors.

Efficient bubble-tower operation is synonomous with the proper control of the outlet-vapor temperatures. Variations in temperatures in the outlet-vapor line are reflected in the quality and yield of the gasoline produced. If these are high the gasoline will be characterized by a higher end-point than desirable or acceptable, which will necessitate a redistillation, or re-run; if low, part of the desired product has been condensed in the tower, resulting in a lower yield, or necessitating a longer run for the complete recovery of the finished product. Uniform tower-temperature regulation results in the production of a uniform grade of gasoline and practically eliminates re-runs, or reduces them to a minimum.

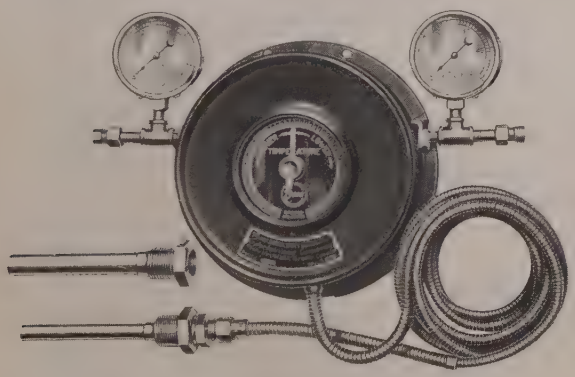


Fig. 69
Single-Duty Capillary-Type Temperature Regulator (Air-Operated) with Separable Well.
For controlling temperatures in bubble towers, etc.

Unit-System Direct-and-Reverse-Acting Temperature Regulator (*Fig. 51, page 27*) in connection with direct-acting diaphragm valves in the by-pass and in the cooling line between the by-pass and the tower, the regulator set to operate one valve at a temperature below that required for the operation of the other. In this application a temperature rise in the outlet vapor tends to open the valve in the cooling line and close the valve in the by-pass line. A drop in temperature in the outlet-vapor line tends to close the valve in the cooling line and open the valve in the by-pass line. The Reverse-Acting Temperature Regulator (*Fig. 69, page 41*) in connection with a direct-acting diaphragm valve in the cooling line would be applicable in the above cooling system only on one condition. The cooling-coil resistance must be sufficiently low so that the amount of oil passing through the coil with the valve entirely open would at all times be sufficient to prevent undue temperature rise. In like manner a Direct-Acting Temperature Regulator in connection with a direct-acting diaphragm valve in the by-pass line would be applicable if it were certain that the cooling-coil resistance was sufficient to prevent at all times undue tower cooling with the valve in the by-pass line entirely open.

Recording Thermometers (*Fig. 18, page 10*) are important units in the system of tower-temperature control, for furnishing a complete record of temperatures existing in the outlet vapor lines from towers. The Bi-Record Recording Thermometer (*Fig. 45, page 24*) will show on a single chart a continuous record of temperatures existing in both the still and tower.

The Direct-Set Recording Regulator (*Fig. 72, page 43*) is widely and successfully used in connection with the operation of fractionating or bubble towers in the refining industry. This instrument is a combination recording thermometer and air-operated temperature regulator with the direct-set feature. When the operator wishes to change the control point of the regulator he has only to turn the direct-set knob, which moves the direct-set adjustment arm to the required temperature on the chart.

Closed Coil Condensers

In the condensation of vapors one of the oldest and most common types of condenser is that known as the "box condenser" which consists of a series of pipes submerged in a tank of cold water. Water circulates through the condenser box, entering at the bottom and leaving at the top, and it is necessary that the water temperature be sufficiently low at all times to effect most efficient condensation. This is especially true during the distillation of the first part of the crude, where principally the lighter and more volatile products come off. The condensed distillates run directly through a "look box" in the receiving or "tail house" to "run-down tanks" where they are held awaiting final disposition.

Instruments Applicable to Closed Coil Condensers

In the condensation of distillates in closed coils proper temperatures can be maintained by means of a Reverse-Acting Temperature Regulator (*Fig. 69, page 41*). This will automatically control the admission of cooling water, dependent on the temperature desired. Recording Thermometers (*Fig. 18, page 10*) are always recommended in systems involving temperature control. Recording, Index and Industrial Thermometers are recommended for use in the condensate lines. Recording and Industrial Thermometers are desirable adjuncts for showing the temperature in the run-down tanks. The character of the distillate may be accurately determined by Hydrometers (*page 99*).

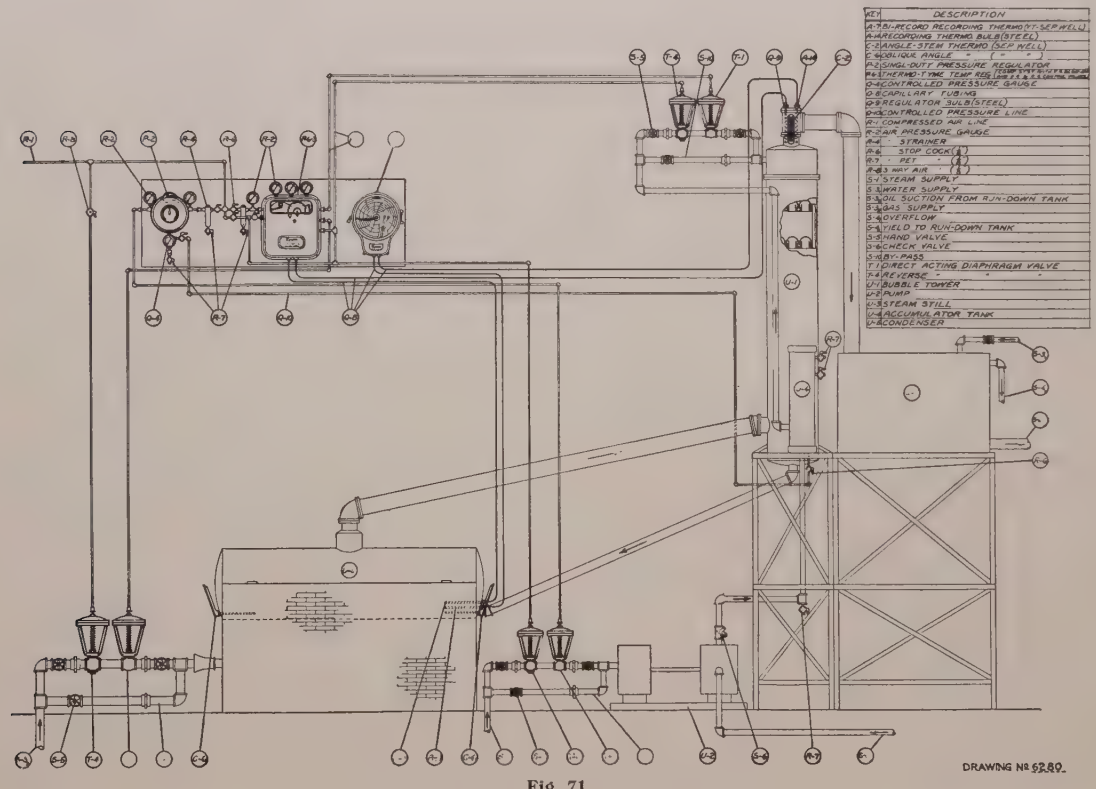


Fig. 71

System of Automatic Control Applied to Still and Bubble Tower

Fig. 72
Direct-Set Recording Temperature Regulator.
Used in the refining and natural-gas gasoline industries, on bubble towers, dephlegmators, etc.

Fig. 72½
Direct-Set Indicating Temperature Regulator.
Used in the refining and natural-gas gasoline industries, on bubble towers, dephlegmators, etc.

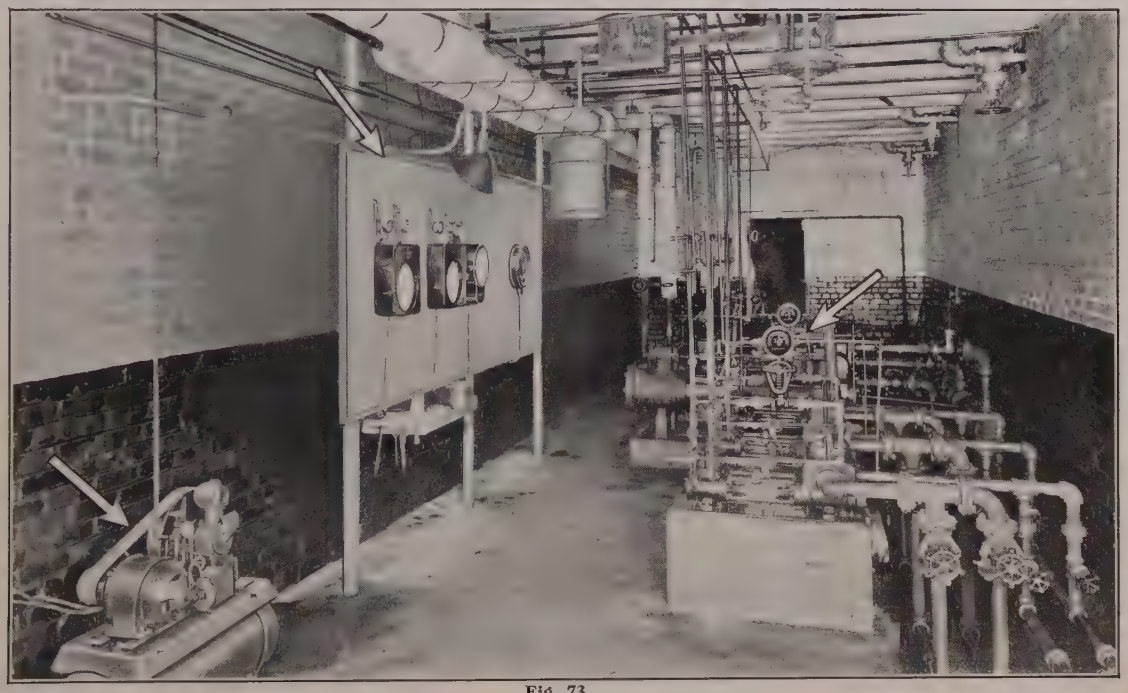


Fig. 73
Installation of Automatic Control applied to Bubble Towers, Showing Direct-Set Recording Regulators recording and controlling temperatures in Bubble Towers, Pressure Regulators maintaining constant pressure in cooling-medium supply lines, and a Compressor furnishing motive power for operating the Controls

The Treating of Light Petroleum Distillates

AGITATORS

The elementary products of petroleum refining, such as gasoline, kerosine, lubricating oil and wax, are at first obtained in their raw state and generally must undergo a subsequent refining treatment before they can be put on the market as finished products. Gasoline and kerosine produced from straight-run distillations in many cases conform in practically all respects to regular standards. Gasoline produced by "cracked" or "synthetic" methods, however, has decidedly objectionable characteristics which necessitate its undergoing a process of purification before it can be put on the market. The purifying process now generally used involves an acid-and-caustic or "doctor" treatment, which is carried out in a system of agitators, as follows: Acid in the desired quantities is first added to the distillate and the mixture is thoroughly agitated by forcing compressed air through the system. The acid then is drawn off and the distillate washed with water. A caustic treatment carried out as before tends to free the gasoline from the remaining traces of acid. This is followed by a second washing.

The system of air agitation as practiced in the above process may result in the loss of volatile products, and this has led to the use of the continuous system of treating. In this process gasoline is circulated through a series of tanks containing in turn the various treating agents. Proper treatment is obtained by thorough circulation of the gasoline through the treating agent in the system.

After the acid-and-caustic treatment, the gasoline fraction may be subjected to the process of steam distillation (*see page 28*) which is the final step in the purification. The raw kerosine distillate usually undergoes a treatment similar to that applied to gasoline. In this case, however, different proportions of the treating agents are used.

The gas oil is not as a rule subjected to any further treatment previous to its disposal as cracking stock, fuel oil, or for use in the manufacture of water-gas.

Instruments Applicable to the Treating of Light Petroleum Distillates

AGITATORS

The Pressure Regulator (*Fig. 62, page 35*) in conjunction with a diaphragm valve in the air-supply line will automatically maintain constant air pressure in agitator systems applied to the treating of petroleum distillates.

Industrial Thermometers (*Fig. 39, page 21*) Index Thermometers (*Fig. 30, page 17*) and Recording Thermometers (*Fig. 18, page 10*) indicate and record temperatures in agitators. These instruments may be procured with lead-plated bulbs as protection against the mediums with which they come in contact.

Hydrometers (*page 99*) are recommended for determining the grade or quality of the treating reagent in the acid-and-caustic treatment as applied to petroleum distillates.

Fig. 74

Recording Thermometer, Suspended-Pen Type

The Manufacture of Paraffin Wax

The manufacture of paraffin wax is one of the most interesting as well as one of the most complex processes in petroleum refining. It embraces operations ranging from high temperatures of distillation to the low temperatures of refrigeration. Few other substances that enter so largely into our modern civilization are less appreciated than paraffin. Its production usually is considered as part of the manufacture of lubricating oils, but if it were a separate industry it would undoubtedly be rated as one of the important ones and its commercial value be better understood.

The wax distillate cut from crude-oil distillations contains the paraffin wax of commerce dissolved in the light, intermediate and heavy lubricants. The separation of the wax and its subsequent refining to finished paraffin may be carried out in two different stages, involving:

1—The Chilling and Pressing of Wax Distillate.

2—The Sweating of Paraffin Wax.

Paraffin wax is not always present in wax distillates derived by distillations using steam, in a state which will permit its removal by the ordinary methods of chilling and cold pressing, as later described. This is true especially in the latter part of the wax-distillate cuts, where the so-called "amorphous wax" occurs. Any attempt to press this material simply results in its going through the filter pad with the oil. It is usually rendered crystalline, or pressable, however, by a process of "dry" or "cracking" distillation, which is simply a distillation without the use of steam, or with a very sparing injection of steam, and should not be confused with the term "cracking" as applied to the production of gasoline from the heavier oils by cracking processes as previously described.

Fig. 75

Electric-Contact Temperature Controls on a Refrigeration Machine. Note also Industrial Thermometers.

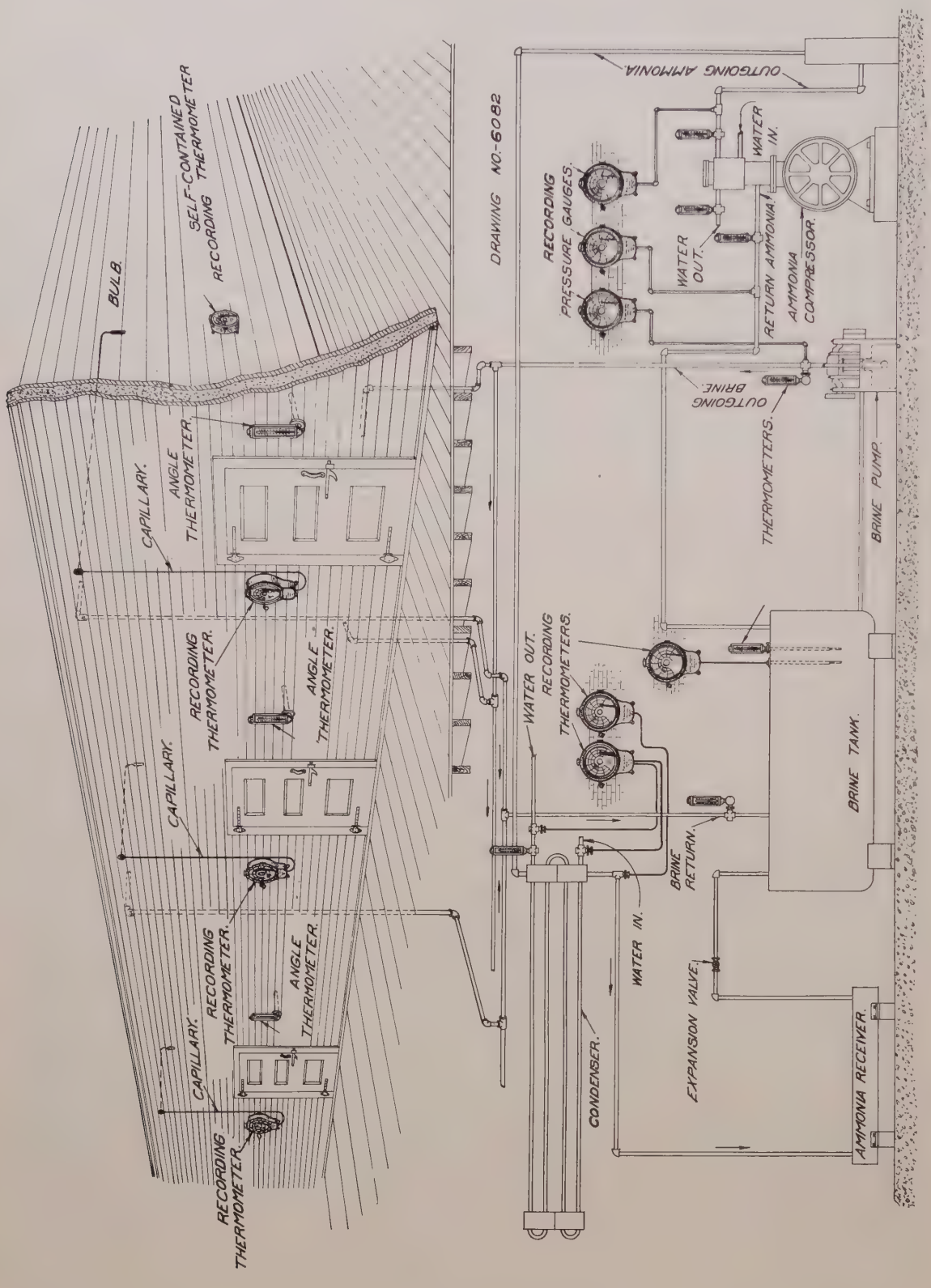


Fig. 76
Showing Application of Instruments on Refrigeration System

Chilling and Pressing of Wax Distillate

Actual separation of the paraffin wax from wax distillate is accomplished by a process of chilling and cold pressing. Chilling is a refrigerating operation, accomplished by circulating the distillate through brine-cooled coils. This causes the contained paraffin to become crystallized, while the oil portion remains fluid. A common type is the double-pipe chiller, consisting of an inner pipe surrounded by an outer jacket pipe. The brine circulates between the two pipes. The cold solidified distillate containing the congealed wax is forced through the inner pipe in counter-current flow to the brine, by means of a screw conveyor. At the expiration of the proper chilling period the solidified wax distillate is pumped into large filter-presses and held under a constant pressure of about 350 pounds per square inch. This forces the oil through canvas filter pads, or blankets, which retain the solid wax.

The two products from the wax distillate chilling and cold-pressing operations are (1) a partly refined paraffin wax called "slack wax", and (2) an oil called "pressed distillate", which subsequently is refined to lubricating oils.

The solid wax, or "slack wax", is removed from the blankets, conveyed to wax "dump" tanks, where it is melted through contact with steam coils, and then pumped to storage to await further treatment.

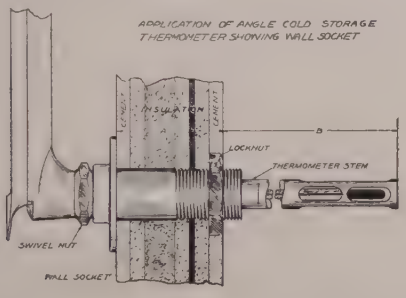


Fig. 77
Wall Socket. Showing Application of Angle Thermometer

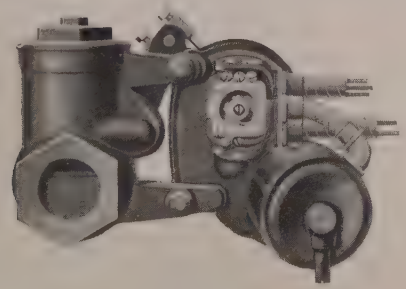


Fig. 78
Motor-Operated Valve

Instruments Applicable to Refrigeration Processes in Wax Plants

The necessity for low-temperature work and the extent of this need in the processing of the wax-distillate cut for the subsequent manufacture of paraffin wax and lubricants make the refrigerating plant one of the most important units in a complete oil refinery. Instruments have a wide range of application in refrigeration processes and special instrument catalogs are devoted entirely to this field.

The correct use of reliable thermometers is an indispensable aid in the efficient operation of refrigeration plants. Temperatures are now considered as the criterion of performance, instead of the old "rule of thumb" method of observing frost lines and gauges.

AMMONIA COMPRESSORS
(Suction and Discharge Lines)

One of the most important thermometer applications is in the suction line of the compressor, since the compressor does the most efficient work at given suction and discharge pressures when the ammonia is returned to the compressor at the saturation temperature, that is the temperature corresponding to the suction pressure.

A thermometer in the discharge line affords an accurate means for determining the mechanical condition of the compressor. If the thermometer in the discharge line registers a temperature much in excess of that which would normally exist in case the suction temperature had been carried within 10° of the saturation point, it is reasonable to conclude that the ammonia gas on the suction stroke is receiving heat from some artifical source, such as leaky safety leads, discharge valves, or pistons. This excess heat will be compounded at the discharge stroke by adding to the heat of compression, and the net result will be excessive discharge temperatures. Discharge temperatures frequently mount without the defect in the compressor being noticeable as far as noise is concerned. For this reason periodical observation of the discharge temperatures is the best source of information on the condition of the compressor.

Fig. 79

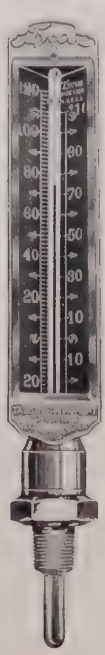


Fig. 80

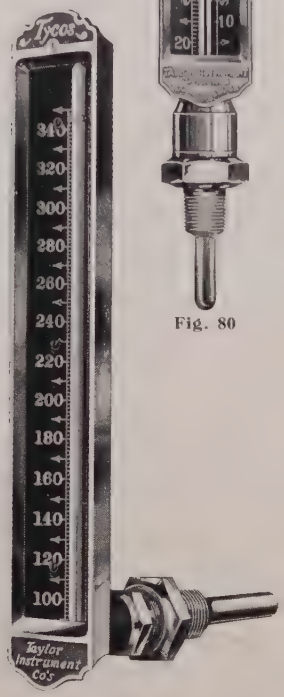


Fig. 81
Industrial Thermometers

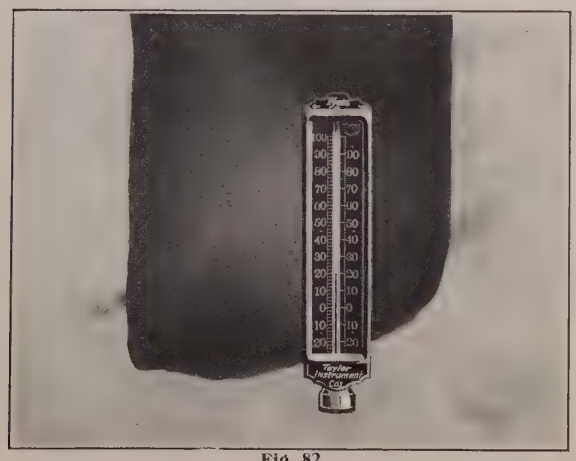


Fig. 82
Insulated-Stem Thermometer Connected to Refrigerating System. Notice heavily-coated pipe, while scale-case is frost-free.

Industrial Thermometers (*Figs. 79, 80, 81, page 48*) are recommended for application in the ammonia suction, ammonia discharge and water-jacket outlet compressor lines.

Recording Thermometers (*Fig. 18, page 10*) will show continuous records of temperatures in ammonia inlet and outlet compressor lines, the Bi-Record Recording Thermometer (*Fig. 45, page 24*) showing a corresponding record of both temperatures on a single chart.

Recording Pressure Gauges (*Fig. 19, page 11*) will show continuous records of pressures in ammonia inlet and outlet compressor lines, the Bi-Record Recording Gauge showing on a single chart a corresponding record of both pressures. A typical application of this instrument is shown (*Fig. 142, page 81*).

AMMONIA CONDENSER LINES

A thermometer is the best possible gauge of condenser performance. The efficiency of a condenser is based in part on the following: 1st, the difference in temperature of the water to and from the condenser; 2nd, the difference in temperature of the water leaving the condenser and of the condensate temperature corresponding to the condenser pressure.

Since this analysis is principally a matter of temperature, thermometers necessarily play an important part. In ammonia-condenser lines the Bi-Record Recording Thermometer (*Fig. 45, page 24*) is recommended for showing the corresponding temperatures in the inlet and outlet water lines. Industrial Thermometers (*Fig. 79, page 48*) likewise are recommended for this application. The temperature of the condenser box can be controlled automatically by means of a Reverse-Acting Temperature Regulator (*Fig. 69, page 41*) which, in conjunction with a diaphragm valve in the cooling line, automatically regulates the flow of water to the condenser box. Recording Thermometers (*Fig. 18, page 10*) and Industrial Thermometers (*Figs. 79, page 48*) are desirable also for showing the temperature of the ammonia, both on entering and leaving the condenser.

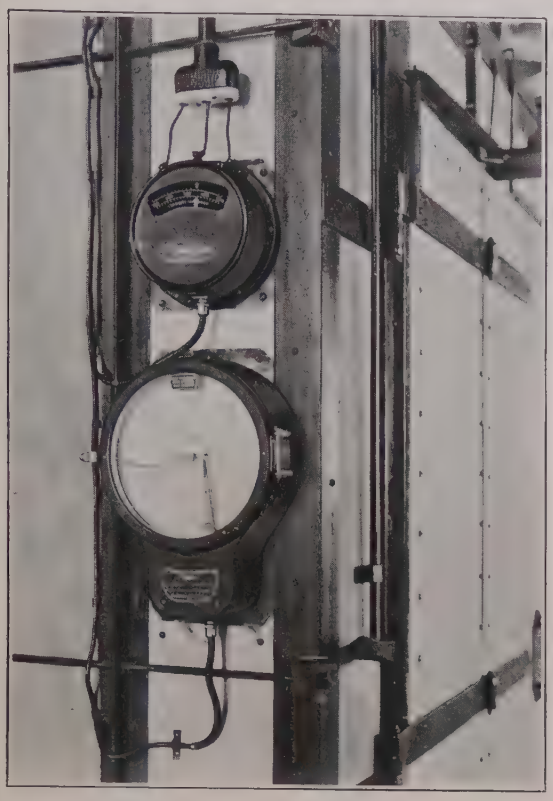


Fig. 83

Close-up of Electric-Contact Temperature Control and Recording Thermometer Installed

BRINE LINES

It is hardly necessary to emphasize the importance of thermometers in brine lines, as no operator has any check whatever on his process unless he makes close observation of the brine temperatures.

Industrial Thermometers (*Fig. 79, page 48*) are furnished in types particularly adaptable to installation in brine lines (*Fig. 82, page 48*). Recording Thermometers (*Fig. 18, page 10*) or Bi-Record Recording Thermometers (*Fig. 45, page 24*) are recommended for furnishing continuous records of temperature in inlet and outlet brine lines.

Brine temperatures are adaptable to automatic regulation by means of Electric-Contact Temperature Control (*Fig. 87, page 50*). This regulator, connected through a relay to an electric switch, will serve to start or stop the compressor in accordance with the temperature desired for the brine.

CHILLING COILS

In the wax-distillate chilling operation thermometers are necessary to deter-

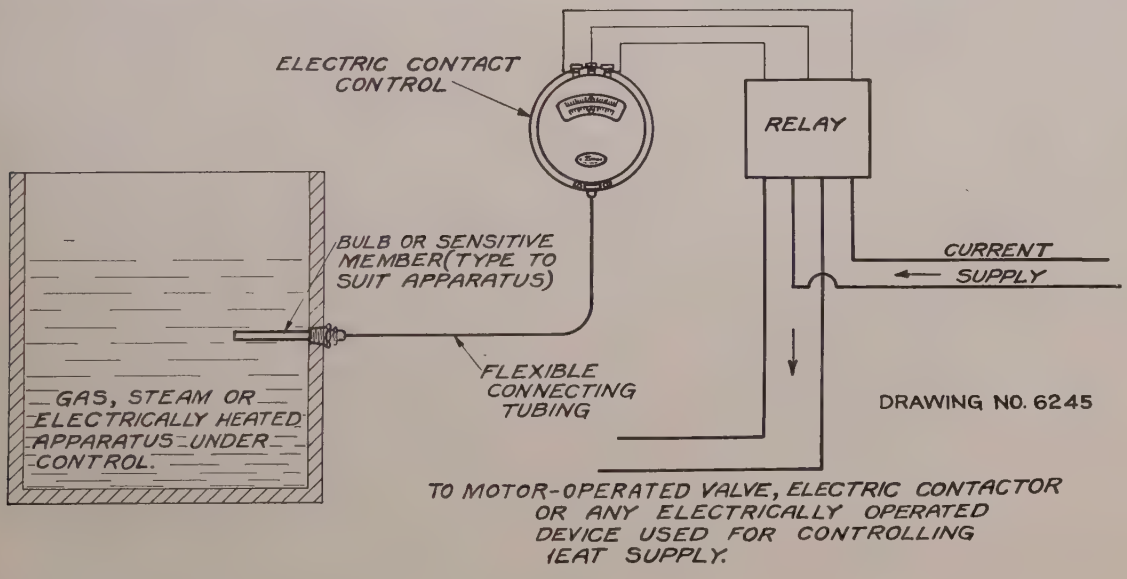

ELECTRIC CONTACT CONTROL
RELAY
BULB OR SENSITIVE MEMBER (TYPE TO SUIT APPARATUS)
CURRENT SUPPLY
FLEXIBLE CONNECTING TUBING
GAS, STEAM OR ELECTRICALLY HEATED APPARATUS UNDER CONTROL.
DRAWING NO. 6245
TO MOTOR-OPERATED VALVE, ELECTRIC CONTACTOR OR ANY ELECTRICALLY OPERATED DEVICE USED FOR CONTROLLING HEAT SUPPLY.

Fig. 84

Diagrammatic Drawing Showing Application of Electric-Contact Temperature Control

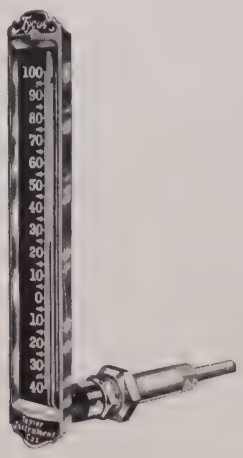


Fig. 85
Angle Thermometer with Insulated Stem

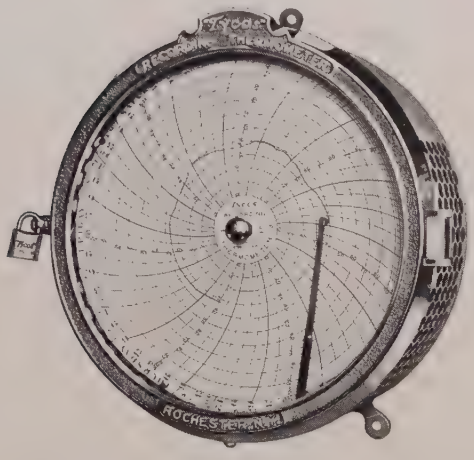


Fig. 86
Recording Thermometer (Self-Contained Type)
For use in press room of Wax Plant, etc.

Fig. 87
Direct-Set Electric-Contact Temperature Control

mine the efficiency of the oil-chilling process. Industrial Thermometers (*Fig. 79, page 48*) are furnished in styles and types especially adaptable to use in oil and brine lines of a chilling unit. Recording Thermometers (*Fig. 18, page 10*) are recommended when a continuous record is desired of temperatures in inlet and outlet oil and brine lines. The Bi-Record Recording Thermometer (*Fig. 45, page 24*) furnishes on the same chart a record of the inlet and outlet temperatures.

The temperature of the solidified oil or mass from the chillers may be automatically regulated by the Electric-Contact Temperature Control (*Fig. 87, page 50*) which, connected through a relay to an electric switch, will start or stop the brine-circulating pump, in accordance with the temperature desired. The Mercury-Actuated Temperature Regulator (*Fig. 48, page 25*) in conjunction with a diaphragm valve in the brine-circulating line is also adaptable to automatic control of outlet-oil temperatures, by regulating the flow of brine to the chillers.

PRESS-ROOM

In the cold pressing operation as applied to wax distillate, Indicating Thermometers (*Figs. 98, 99, page 55*) are recommended for inside observation of press-room temperatures. Self-Contained Recording Thermometers (*Fig. 86, page 50*) are recommended also for installation in the press-room. Recording Thermometers (*Fig. 18, page 10*) are recommended for outside observation of press-room temperatures. Industrial Thermometers (*Fig. 79, page 48*) are applicable for installation in the oil line to the press.

Instruments Applicable to Slack-Wax Storage Tanks

Where steam is used as the heating agency the temperatures in the slack-wax storage tanks are maintained automatically by Capillary-Type Temperature Regulators (*Fig. 48, page 25*) in conjunction with diaphragm valves in the steam supply line. Industrial Thermometers (*Figs. 24, 25, page 15*) and Recording Thermometers (*Fig. 18, page 10*) are recommended for indicating and recording slack-wax temperatures in storage tanks, or at any point desired.

The Sweating of Paraffin Wax

Slack wax generally contains from 30 to 60 percent of commercial paraffin, the remaining 40 to 70 percent being oil and poor-quality paraffin, which could not be removed by the cold-pressing operation previously described. The removal of these products and the consequent recovery of the commercial paraffin is accomplished by subjecting the slack wax to a process of heat treatment known as "sweating". Sweating in its broader sense may be defined as the separation of oil and low-melting wax from crystalline paraffin wax of commercial quality by the gradual application of heat to a solidified mass of the mixed ingredients. This is in reality a melting-out process and is based on the latent heat of fusion or the progressively higher melting points of the various substances making up slack wax.

The construction of a wax-sweating unit is somewhat on the following order: A series of pans is arranged vertically in a sweat-house or oven, in stacks from four to twelve pans high. These pans usually are eight to ten feet in width, twenty to sixty feet in length and are built generally to accommodate a six-inch to fourteen-inch wax cake. Each pan is built with a substantially-supported screen placed near the bottom and is equipped also with a series of coils in a fixed position slightly above the screen, the coils to be used for continuous water circulation. In the sweat-house, or oven, steam coils are arranged along the sides or bottom of the room to provide the necessary room heat.

In refinery practices the wax-oil mixture, or slack-wax, is pumped from the slack-wax tanks into the sweating pans, in which there is sufficient water to float the mass above the screen but to permit it to cover the pan coils completely to the necessary depth. The mixture is then cooled to a solid cake by the circulation of cold water through the coils, and the water supporting the cake thus chilled is drawn from the pan, leaving the solidified cake of slack-wax resting on the screen. The oven then is closed and the temperatures of the room and of the water in the coils gradually and concurrently raised. The temperature of the circulating water is regulated by the direct admission of steam into a hot-water tank, from which circulation is continuously effected by the aid of pumps.

The gradual increase of heat to which the wax mass is subjected tends to separate out the oil and the low-melting waxes of progressively higher melting points. As the temperature is

Instruments Applicable to Wax Sweaters

Industrial Thermometers (*similar to Fig. 147, page 82*) are furnished in standard forms with open easily-visible scales, making them particularly adaptable for showing temperatures inside the sweater.

Industrial Thermometers (*Figs. 24, 25, page 15*) are furnished in standard straight or angle-stem forms for showing temperatures in water-circulating lines.

Cup-Case Thermometers (*Figs. 97, page 55*) are especially suitable for taking temperatures of oil or molten wax in tanks. Engraved Thermometers (*Fig. 156, page 94*) likewise are adaptable for determining the melting point of the wax or the various wax-oil mixtures from the sweating process.

AUTOMATIC CONTROL FOR WAX SWEATERS

In the process of wax sweating the chief object is to obtain a maximum percent of scale of the desired melting point, having a minimum oil content, this to be accomplished in the shortest time practicable, with a minimum expenditure of power and labor.

The temperature of a wax-sweating room is controlled ordinarily by hand valves in the steam lines, in accordance with room temperatures as shown by a thermometer hanging in a certain location in the room. When the temperature shown is higher than the schedule called for the steam supply is cut down, and when it is shown lower the steam supply is increased. The temperature of the circulating water usually is maintained lower than the room temperature and it likewise is controlled by a hand-valve in the steam-supply line to the hot-water tank, in accordance with the temperature as shown by a thermometer in the water circulating line.

From the nature of the operation and the material processed, the element of temperature control in wax sweating is very important.

An undue increase in temperature will melt out some of the scale, which is the product desired, and in addition will close up the cells to such an extent that the final product will contain

increased the wax cake in the pans becomes more and more free of oil until the desired separation is effected.

In sweating operations generally the first oil off the cake, to a melting point for example of 90°F. on the stream, is taken as foots oil. Some plants recycle this material through the process of pressing and sweating; others consider the cost of operation greater than the gain and utilize it as fuel oil.

From 90°F. melting point on the stream, to another fixed melting point, as for example 112°F., the wax-oil mixture from the pans is run into separate tanks and held as intermediate paraffin wax. During the late war there was considerable market for this material, but now the market is more limited and it is almost universal practice among refiners to recycle this product through the wax-plant apparatus, by mixing it with the incoming sweating stock.

a relatively high percentage of oil. This occurrence represents, too, a needless expenditure of steam.

An undue decrease in temperature will retard the process. The outer or exposed surfaces of the crude slack in the pans will become chilled, arresting the flow of oil from the core of the slack-wax cake and upsetting the balance that would be possible if uniform control of temperature were assured. The importance of the above factors is better recognized in the possibility or probability of their continual occurrence over a period of hours throughout the entire duration of the run.

In the manual control of the wax-sweating process, considered in the light of the standards for determining proper condition and maintenance of temperatures, human weaknesses and limitations inevitably give rise to imperfections in control.

A system of control has been designed for automatically regulating temperatures in wax sweaters, in accordance with a predetermined time and temperature schedule. The actual control is based not so much on spot temperature as on representative room-temperature conditions allowed through the proper type of construction of the control.

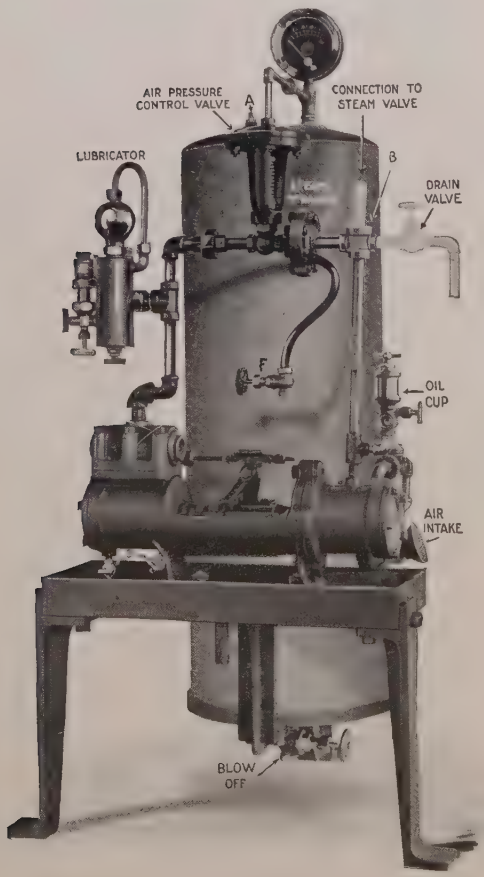


Fig 88
Steam-Driven Air Compressor

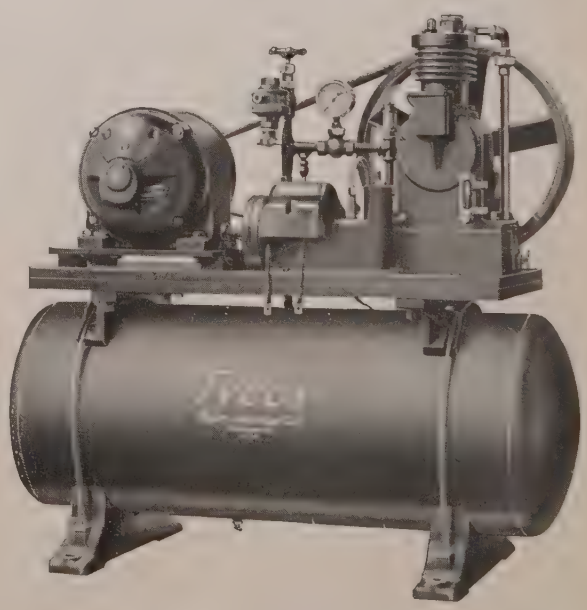


Fig. 89
Motor-Driven Air Compressor

The paraffin remaining in the pans, when the stream melting point has reached a predetermined temperature and the operation is considered complete, is called crude scale wax. It has a melting point usually of 122° to 126° and an oil content of about ½ to 1 per cent, both tests depending on the method of preparing the slack wax before sweating and upon the method used in the sweating run.

The crude scale is melted out of the pans, and in special cases, for special contracts, is chemically treated and filtered through fullers' earth. For ordinary sale purposes however, it is only filtered through fullers' earth and barrelled, sacked, or moulded into cakes in a manner later described, and sold as finished paraffin.

Wax sweating is a process which requires extreme care and much patience. The length of time of the sweating and the rate of rise of temperature per hour differs very widely in different plants. Most operations require at least thirty hours for the completion of the cycle, although in some cases a maximum of 110 hours has been necessary to accomplish the desired result. All processes are continued until the scale in the pans conforms to the desired standards as regards melting point and oil content.

In general many of the methods of wax sweating are very inefficient, and all the wax actually contained in the slack wax is not recovered. An article by L. D. Wyant of the Bureau of Mines, published in "The Oil and

In manually-operated systems of control the most experienced operator can compensate for variations in temperature only after such changes are indicated by a thermometer. Temperature Regulators anticipate, as it were, changing temperatures, and compensate for them automatically.

It would be impracticable to outline here a scheme of automatic control applicable to all sweating operations, as the most efficient wax-sweater controls are designed and applied to each particular process in accordance with special conditions pertaining thereto. In any installation engineers make a preliminary survey, draw up plans and specifications, personally supervise actual installations and test the equipment as finally installed. The System of Automatic Control for Wax Sweaters is used in many refineries and its practicability, efficiency and superior worth have been amply demonstrated.

Fig. 91
Air Strainer

Fig. 90
Pressure Regulator

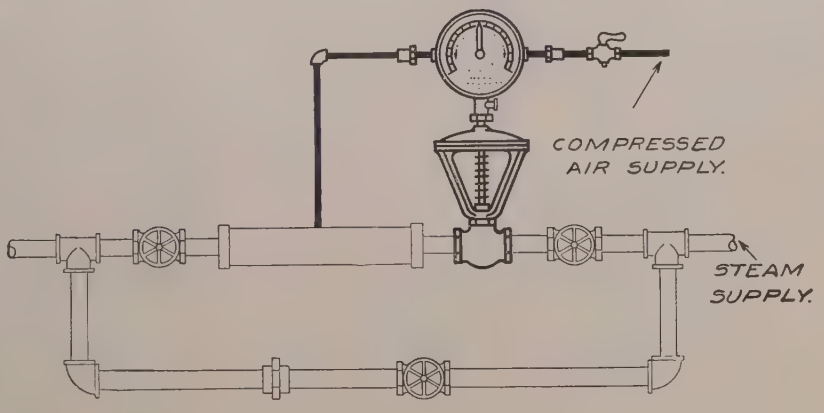


Fig. 92
Showing method of connecting Pressure Regulator to steam-supply line

Gas Journal", shows that among a list of different refineries the efficiency of their sweating processes usually ranged from 24 to 85 per cent. That is, in some refineries only 24 per cent of the total wax available in slack wax was recovered by the process of sweating. The complete recovery of all commercial paraffin in slack wax is practically impossible, due to the nature of the physical process designed to effect the recovery and the natural characteristics of the products making up slack wax. The inefficiency of many sweating operations can be attributed partly to the natural difficulties attendant on the sweating operation. One of the greatest of these lies in the accurate control of the heating temperature. Uneven temperatures are reflected in the quality and yield of wax produced and in the time necessary for the completion of the operation. A sudden undue temperature rise in any or all parts of the room will cause some of the desirable wax to be melted from the cake. A sudden undue temperature drop will cause the cooling or hardening of the parts of the wax cake affected, with an attendant lag in the operation.

Fig. 93
Bi-Record Recording Thermometer

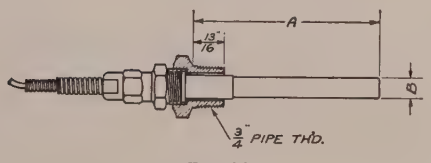


Fig. 94
Union Connection for Recording Thermometers, Index Thermometers and Regulators

The Double-Duty Temperature-and-Time Regulator (*Fig. 95, page 54*) as the essential unit in the system of control will at all times regulate both room and water temperatures and maintain them throughout any rising temperature schedule in any fixed or variable relationship, which the investigation of the sweater and the material being processed would reveal as desirable.

The System of Automatic Control for Wax Sweaters, properly applied, through its maintenance of proper temperatures from representative conditions and its elimination of the human element, will effect an economy over manually-operated processes. This may be reflected in an increased yield, higher quality of product as concerns melting point and oil content, cutting down the time of the process, or conservation of steam, dependent on the result which it is desirable or practicable to work for.

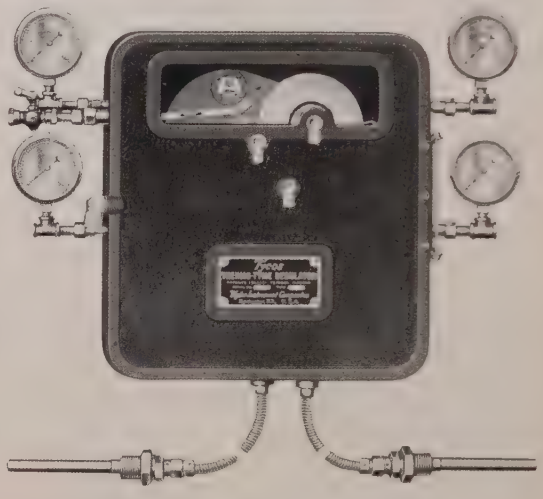


Fig. 95
Double-Duty Capillary-Type Temperature-and-Time Regulator (Air-Operated)

This instrument is one of the primary units in connection with the System of Automatic Control for Wax Sweaters, where both room and circulating-water temperatures are controlled in any fixed or variable relationship throughout any rising temperature schedule.

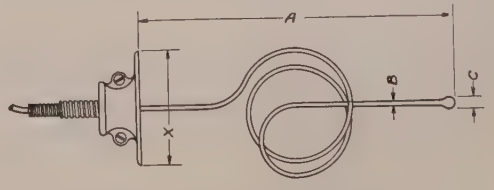


Fig. 96
Capillary Bulb and Clamp-Flange Connection for Recording Thermometers, Index Thermometers and Regulators

The Handling of Paraffin Wax

WAX SCALING MACHINES

The preparation of paraffin wax for shipment sometimes is accomplished by the wax scaling or chipping machine. In this operation the molten wax is run into a bath or pan-like container. A cast-iron cylinder revolves horizontally above the wax in such a way that only a small part of its circumference is submerged in the wax at one time. Cold water is circulating through the drum and the chilling effect thereby produced causes a deposition or congealing of a thin film of wax on the surface of the drum. This film is continuously and automatically scraped off directly into the containers in which the wax is to be shipped.

WAX MOULDING MACHINES

Refined wax sometimes is moulded into cakes and shipped in this form. In the Gray Moulding Process, the operation is somewhat similar to that of the filter press. Moulds and cooling plates are arranged alternately. The moulds are so placed as to allow a flow of molten wax into the mould to make up for the shrinkage caused in cooling. The chilling of the wax is accomplished through the circulation of cold water through the cooling plates, this process usually requiring from two to four hours.

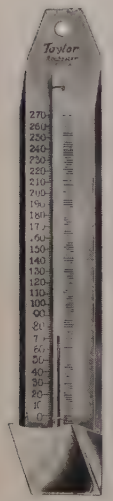


Fig. 97
Cup-Case Thermometer, for Testing Oil, etc.

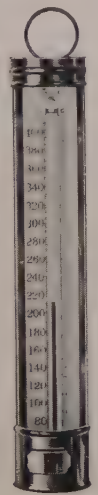


Fig. 98
Tin-Case Thermometer

Fig 99
Galvanized-Iron Case Thermometer, for Cold-Storage Rooms, etc.

Fig. 100
V-Shape Scale, Strong Metal Case Wall Thermometer

Instruments Applicable in the Handling of Paraffin Wax

WAX STORAGE TANKS

Finished paraffin wax usually is stored in a molten condition over indefinite periods, in large steel tanks in which steam coils are inserted to provide the necessary heat to keep it in this condition. Temperature Regulators (*Fig. 69, page 41*) will automatically control the temperature of wax during storage, by regulating the amount of steam through the system by means of diaphragm valves in the steam lines. Industrial Thermometers (*Figs. 24, 25, page 15*) and Recording Themometers (*Fig. 18, page 10*) also are applicable for indicating and recording temperatures of the wax during storage.

WAX SCALING MACHINES

In wax scaling or chipping machines temperatures in the wax tank are controlled automatically by means of the Direct-Acting Temperature Regulator (*Fig. 69, page 41*) in conjunction with a diaphragm valve in the steam-heating supply line. The Reverse-Acting Temperature Regulator (*Fig. 69, page 41*) will automatically control the temperatures in the drum by means of a diaphragm valve in the water line. The Double-Duty Compound-System Temperature Regulator (*Fig. 109, page 60*) is a single instrument which will control both the temperatures in the wax bath and the drum, by means of diaphragm valves in the steam-heating and the water-cooling lines.

Industrial Thermometers (*Figs. 24, 25, page 15*) and Recording Thermometers (*Fig. 18, page 10*) are recommended for indicating and recording temperatures in the wax tank and drum.

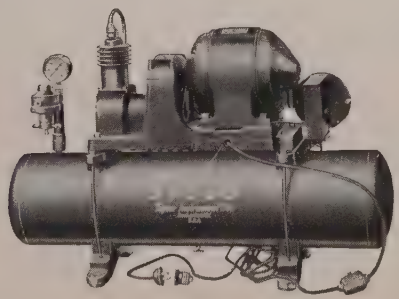


Fig. 101
Motor-Driven Air Compressor

The Manufacture of Lubricating Oils

The chilling and pressing of the wax-distillate cut is a basis for the manufacture of lubricating oils. Pressed distillate, which is simply the wax distillate with the wax removed, is separated into the various grades of lubricants, through distillation by fire and steam. This gives a light lubricating oil known as non-viscous neutral, and a heavy lubricating oil known as viscous neutral, the latter remaining as a residue in the still. Filtration through fullers' earth sometimes serves to sufficiently cleanse or purify the non-viscous lubricants. The heavy viscous neutrals however undergo a chemical treatment with acid and caustic, which procedure seems to be necessary for destroying undesirable colors and odors and for the general improvement of the lubricating qualities.

This treatment is carried out in a series of agitators comprising treating and neutralizing, or wash, agitators. Where concentrated acid is always present the agitators may be steel lined; where weaker acids are present, as would occur in wash agitators, lead lining for the unit is necessary.

Lubricating-oil treatment in the various units may be carried out at temperatures from 150° to 200°F.

A final treatment by filtration through fullers' earth serves to further improve the product. One of the more common filters is the vertical type. The essential features of this system consist of a series of drainage plates interlaid with fullers' earth on canvas blankets through which the oil flows. The flow of the oil is accomplished either by gravity or pressure. Filtering operations usually are carried out at temperatures dependent on the quality of oil being filtered, and the temperature of the filter ordinarily is maintained by means of steam coils.

THE RECLAMATION OF FULLERS' EARTH

At the conclusion of the filtering process, the fullers' earth itself must be treated or cleansed, before it can be used a second time. The regeneration process is accomplished by burning out the tarry matter at a temperature high enough for combustion, but not so high as to disintegrate or glaze the earth.

Two common types of apparatus used for fullers'-earth burning are the vertical oven and the rotary kiln.

Instruments Applicable in the Manufacture of Lubricating Oils

AGITATORS

Industrial Thermometers (*Figs. 24, 25, page 15*), Index Thermometers (*Fig. 30, page 17*) and Recording Thermometers (*Fig. 74, page 44*) are furnished with lead-plated bulbs applicable for indicating and recording temperatures existing in lubricating-oil agitators.

FILTER PLANTS

Temperatures in the hot-filter room are shown accurately at all times by the use of the Indicating Thermometer (*Figs. 98, 100, page 55*). Recording Thermometers (*Fig. 74, page 44*) are desirable for showing a continuous record of filter-room temperatures. Industrial Thermometers (*Figs. 24, 25, page 15*) and Recording Thermometers (*Fig. 74, page 44*) are similarly applicable for showing temperatures of the oil from tanks into the filter.

Where oil-or filter-room temperatures are dependent on the use of steam as a heating agency, the temperature is controlled automatically by means of a Temperature Regulator (*Fig. 69, page 41*). This controller, in connection with a diaphragm valve in the steam supply line, will regulate the admission of steam in accordance with the temperature desired.

FULLERS'-EARTH BURNERS

In the burning of fullers' earth, a knowledge of kiln temperatures is necessary in order to secure efficient heating and at the same time prevent overburning. Indicating Pyrometers (*Fig. 26, page 16*) are especially adaptable for clearly and accurately showing kiln temperatures. By use of the Rotary Switch (*Fig. 27, page 16*) readings from as many as twelve different kilns can be shown on a single indicating instrument. The Rotary Switch is also furnished standard for six stations. The Push-Button Pyrometer Switchboard (*Fig. 33, page 18*) also is available for use with pyrometers.

Where continuous records of kiln temperatures are desirable Recording Pyrometers are applicable in the single (*Fig. 57, page 31*) or the duplex (*Fig. 42, page 23*) recording type.

In the vertical oven the earth is gradually fed by gravity from an elevated reservoir down an incline, counter-current to and in intimate contact with the hot gases from the burners underneath.

The rotary kiln consists of a shell mounted on rollers, and is revolved by a train of gears. The kiln is inclined and the earth enters at the upper end and is discharged through an opening at the lower, or front, end. Burners are located in the front of the kiln, the hot gases passing through come in contact with the earth and leave at the rear of the kiln where they meet the incoming charge.

Treatment of Still Bottoms, or Still Residues

At the conclusion of a fire-and-steam distillation applied to a paraffin-containing crude, the material remaining in the still is usually termed "cylinder stock" or "steam-refined stock". This is used as a basis for the manufacture of "bright stock" and "petrolatum". The "bright stock" cannot be recovered by the ordinary process of chilling and cold pressing, for the waxy material present in the mass is existant in the amorphous, or non-crystalline state. It is undesirable also to dry-distill or crack the cylinder stock, in order to render it pressable, for this operation partly destroys the valuable quality of the lubricating oil.

The Cold-Settling Process

The separation of the bright stock from the amorphous wax contained in the steam cylinder stock is accomplished by the process of "cold settling".

In this method, the "still bottoms" after first being treated to remove color, and asphaltic bodies in case the latter are present, are mixed with naphtha in the desired proportions and the mixture run into tanks at a temperature around 100°F. The tank then is cooled down gradually through the circulation of water first, and then of brine through coils supported in the tank. When the mixture has cooled to 8° to 10°F. the mass is allowed to stand for twenty-four hours, while the wax-like materials settle to the bottom of the tank. The two layers of material are then pumped off separately. Occasionally a second, or middle, portion is pumped off and is introduced in the settling tank with the next batch. The bottoms from the cold-settling process contain

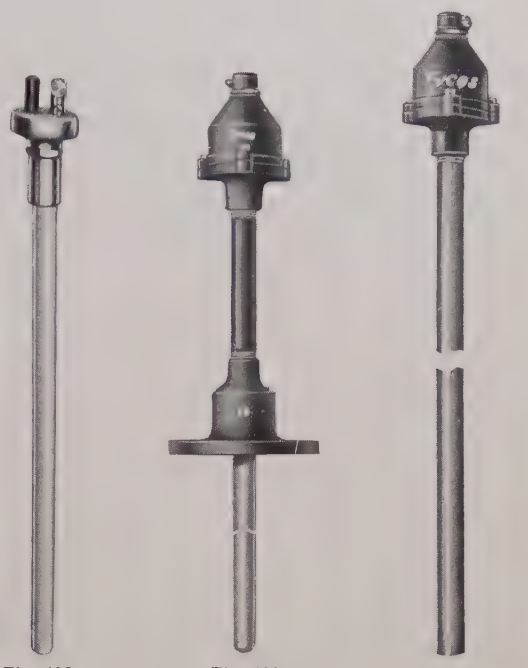


Fig. 102 Fig. 103 Fig. 104
Thermocouples

Instruments Applicable to the Cold-Settling Process

Industrial Thermometers (*Fig. 85, page 50*) are furnished standard for showing temperatures in cold settling tanks. Recording Thermometers (*Fig. 18, page 10*) are used extensively in cold settling tanks, for showing a continuous record of temperatures and time consumed during the chilling operation.

Index Thermometers are furnished (*Fig. 108, page 59*) for showing clearly the temperatures existing in cold settling tanks, where from inconvenience of observation the use of a mercury-column indicating thermometer is impracticable.

The Distance-Reading Electric Transmitting Recording Thermometer (*Fig. 46, page 24*) is designed for recording temperatures at a distance of several hundred or several thousand feet from the system where such temperatures are to be measured.

the petrolatum, while the top portions usually are the bright cylinder stocks. Each fraction is separated from the naphtha by steam distillation. The bright stock then is ready for compounding into the various grades of lubricants. The petrolatum, after the filtration process, is the basis of the various finished petroleum salves and greases.

The Sharples Process

In the manufacture of bright stock the separation from the amorphous wax contained in the "steam-refined stock" or "cylinder stock" is accomplished also by the application of the centrifuge. This principle is an embodiment of the Sharples Process. The advantages claimed for this process lie in continuity of operation, lower cold test for and bigger yield of bright stock and a higher quality of petrolatum. It is applicable not only to the de-waxing of steam-refined stock, but also can be effectively applied to the de-waxing of long residuum. "Long residuum" is a descriptive term applied to a steam-still residue which consists of cylinder stock and heavy distillate fractions which are ordinarily distilled off. Long residuums which may be treated by the Sharples Process are those having fire tests around 475°F. and may constitute about 25% of the crude. This material comprises practically all the lubricating oil of the crude. Ordinarily it is separated into lubricating oil and paraffin wax by the aid of a preliminary dry-distillation process which renders the wax susceptible to a process of chilling and pressing, but at the same time lowers the quality of the lubricating oil. By the Sharples Process the amorphous wax is separated from the oil without the agency of dry distillation as a primary measure.

In brief, the operation of the Sharples Process is as follows: the cylinder stock, or long residuum, is first filtered through fullers' earth to the desired color. In case the stock is from a mixed-base crude, the filtration is preceded by an acid treatment to effect the removal of the asphaltic bodies. The material then is mixed with the right proportions of naphtha. This mixture is heated to a temperature of from 100° to 110°F. and agitated to insure complete solution. The dilute stock then is pumped into tanks and chilled gradually through a period of forty-eight hours, with agitation until the oil has been reduced in temperature to minus 10°F. This entails cooling at the rate of about

Instruments Applicable in the Sharples Process

In the Sharples Process, Industrial Thermometers (*similar to Figs. 24, 25, page 15*) are adaptable for installations in the incoming and outgoing brine lines, in the chilling tanks, in the oil line from the chilling tanks to the centrifuges and in the oil run-down tanks. Thermometers for these various applications are furnished standard in a 12″-scale length with range from minus 40° to plus 100°F.

Industrial Thermometers are furnished also in a standard range from 30° to 160°F., for showing temperatures in the water tanks supplying water to the centrifuges, and temperatures in the mixing tanks where the oil is prepared previous to its being chilled.

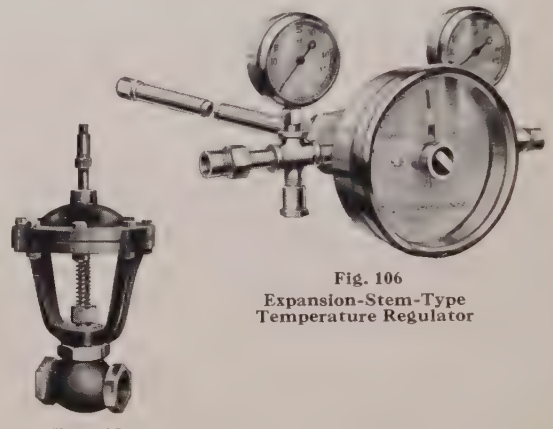


Fig. 106
Expansion-Stem-Type Temperature Regulator

Fig. 105
Diaphragm Valve

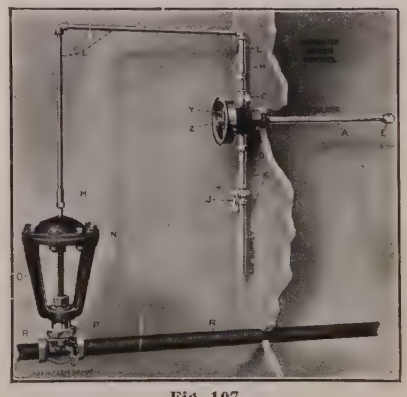


Fig. 107
Typical Installation of Direct-Acting Expansion-Stem-Type Temperature Regulator and Direct-Acting Diaphragm Valve

2½°F. per hour. The chilled mixture then is passed through centrifuges, from which the wax is discharged at one side and the oil at another.

Cooling in this system is accomplished by the circulation of brine. The brine temperatures usually are maintained not lower than ten degrees below the required temperature of the oil at any given time in the chilling period. This is accomplished through the hand operation of a needle valve, which admits just enough cold brine with the returning brine from the continuous circulating system to secure the desired temperature in the chiller. Brine temperatures in the chilling coils of the various tanks require separate control. One of the features in the centrifugal separation of the wax from the lubricating oil in the Sharples Process is the continuous discharge of wax from the machines. In connection with this operation a special rotor has been constructed. Water at a temperature of about 140° F. is fed into the head of the machine by jets, and this water, known as carrier liquid, maintains itself as a flexible carrier on the periphery of the rotor of the machine. Thus the wax is deposited on the surface of the water and carried by it from the machine. Hot water as a liquid carrier tends to melt the wax as rapidly as it is discharged from the machine, so that it will flow by gravity to the separators, where the water and wax are separated by gravity.

The wax-free oil leaves the system at a temperature of minus 5°F. From here it passes to heat exchangers and thence to the reduction stills.

The wax flows to a separate tank and then is pumped to storage or reduction.

Dry Distillation of Petroleum (Tar Stills)

In the refining of petroleum, a procedure in general use involves a complete distillation of the crude without the aid of steam. This is commonly spoken of as a "dry", or "cracking", distillation, and is applied to both asphaltic-base crudes and to paraffin-containing crudes containing asphalt in such quantities as to prevent the manufacture of cylinder stock.

This method as applied to paraffin-containing oil gives a paraffin distillate from which the wax can be removed by the ordinary methods of chilling and cold pressing, without the necessity of subjecting the distillate to a re-run, as in the case of crude-oil distillations with the aid of steam.

Recording Thermometers (*Fig. 18, page 10*) are applicable for showing a complete record of temperatures and the rate at which chilling is accomplished in each chilling tank.

Bi-Record Recording Thermometers (*Fig. 45, page 24*) are desirable for recording on a single chart temperatures of both the incoming and outgoing brine. As there is practically a fixed differential between the temperatures of the outgoing brine and the return brine from the chilling tanks, the Bi-Record Recording Thermometer will help materially in the control of the flow of brine through the chilling tanks and also check up on any undue loss of refrigeration, due to poor insulation or pump trouble.

In the Sharples Process, temperatures in the hot-water tank are controlled automatically by the Expansion-Stem-Type Temperature Regulator (*Fig. 106, page 58*) in conjunction with a diaphragm valve in the steam supply line.

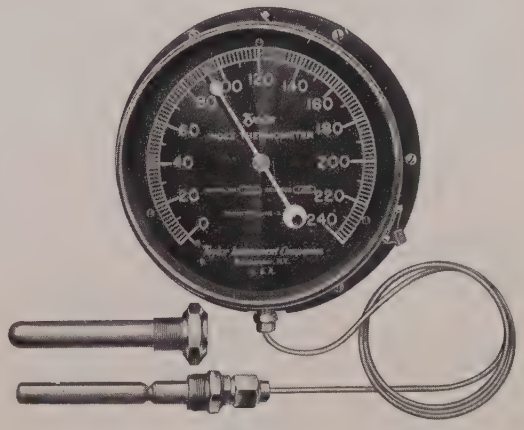


Fig. 108
Index Thermometer
Furnished with specified ranges, for indicating temperatures in Stills, Vapor Lines, Towers, Refrigeration Processes, etc.

Instruments Applicable to Tar Stills

In dry distillations as carried out in so-called tar stills, the same application exists for Industrial Thermometers, Index Thermometers, and Recording Thermometers as in Fire Stills previously described, both in the still itself and also the vapor line from the still. The instruments themselves would necessarily have a higher range however, when applied to tar stills due to the fact that dry distillations as here effected may

In the above practice, the lighter products, consisting of the gasoline, kerosine and gas-oil fractions, are distilled off and the material remaining in the still consists of a heavy black residue containing paraffin wax and lubricating oils. This material then is subjected to a more rapid rate of distillation, either in the same stills or in separate stills called "tar stills". The products from this distillation are a certain percentage of cracked distillate, paraffin distillate, a small amount of heavy distillate known as wax tailings, coming over towards the end of the operation, and coke which remains in the still upon the completion of the process.

Compounding of Petroleum Products

Petroleum products are sometimes subjected to a process of blending and compounding in order to produce other compounds meeting different specifications as to viscosity, gravity, cold test, etc. This is practiced both with the light-oil distillates and the heavy or lubricating distillates. Various oils other than petroleum oils are used in compounding processes. Certain grades of lubricants are compounds of heavy petroleum distillates and certain animal or vegetable oils. Various types of greases are compounds in various proportions of petroleum stocks and animal or vegetable fats or waxes.

BLOW TANKS

Vegetable oils, such for example as rape or cottonseed oil, are used commonly for blending with petroleum lubricating oils. These oils are subjected first to an oxidation treatment however, by being blown with air at high temperatures to produce the characteristics desired for blending. The oils are then commonly termed "blown" oils.

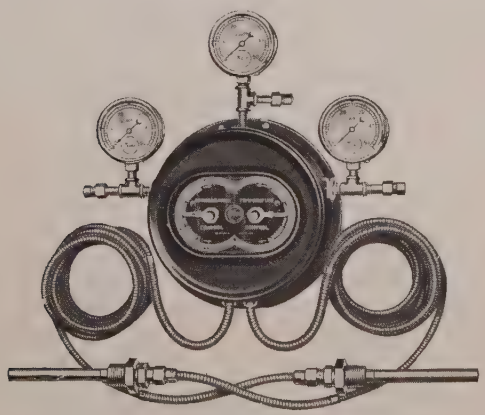


Fig. 109
Double-Duty Compound-System Capillary-Type Temperature Regulator (Air-Operated).
For controlling the temperature of two different mediums, as in wax-scaling machines. Also for controlling temperatures in steam-heated apparatus, and for discharging condensation.

be carried out at higher temperatures than in regular fire or fire-and-steam stills. For example, Index Thermometers with range 100°-800°F. would be satisfactory for fire stills, while for tar stills a range from 200° to 1000° would be desirable.

Instruments Applicable to Compounding Processes

BLOW TANKS

In the blowing of vegetable oils, making them suitable for blending, the blowing or oxidation process is accompanied by relatively high temperatures. Steam is used to boost to the temperature desired, and cooling water employed in case the temperature generated by the oxidation process becomes too high.

Temperatures in "blow tanks" are controlled automatically by the Double-Duty Unit-System Temperature Regulator (*Fig. 51, page 27*). This regulator will admit steam necessary to maintain the temperature desired, and in case the heat of reaction or oxidation is sufficient to carry the temperature above this point, the regulator will admit the necessary cooling water.

GREASE KETTLES

In grease plants comparatively high temperatures are employed during the compounding operations. Compounding processes in grease manufacture usually are carried out in a kettle-like receptacle with a jacket into which steam is admitted to provide heat necessary for the operation. The Temperature Regulator (*Fig. 48, page 25*) in conjunction with a diaphragm valve in the steam supply line will automatically control kettle temperatures by the proper admission of steam to the jacket. The Double-Duty Compound-System Temperature Regulator (*Fig. 109, page 60*) will in like manner automatically control the temperatures in the apparatus, and at the same time will provide an efficient means for discharging the condensation from the jacket. Industrial Thermometers (*Figs. 24, 25, page 15*) and Recording Thermometers (*Fig. 74, page 44*) are specially recommended for indicating and recording temperatures in grease kettles.

Barrel Manufacturing

The major part of the finished petroleum products is shipped in tank cars. Smaller quantities however, especially when intended for domestic consumption, are shipped in wooden barrels. Some refineries manufacture their own barrels and in the case of large refineries the barrel-making unit may be a complete plant in itself. The processes used in connection with barrel making are dependent on the nature of the raw material with which the operator has to work. Barrel staves are sometimes bought already dried and ready for immediate assembly. However, they are generally purchased in the raw or undried condition and this necessitates their being subjected to a kiln-drying process before they are in proper condition for assembly. Barrel assembly generally is carried out in accordance with standardized practices for which certain types of mechanical appliances have been developed. The essential steps in the procedure are as follows:—the staves are first inserted in a head or block in ordinary position and then are wedged by means of a heavy iron ring around their base. This is

Instruments Applicable in Barrel Manufacturing

DRY KILNS

The operation and control of dry kilns in barrel plants is identical in principle with the practices employed in ordinary lumber dry kilns. In this connection the two most important factors to be considered are temperature and humidity, and the proper control of these conditions is necessary for efficient dry-kiln operation. Experienced dry-kiln engineers recommend automatic control of temperature and humidity in dry kilns as an aid to more successful drying. To quote from a publication of the Forest Products Laboratory, Madison, Wisconsin,—"The use of automatic control valves is recommended for practically all kinds of kiln drying, because a more even temperature can be maintained, injury from excessive temperatures avoided, and loss of time from excessively low temperatures prevented".

The system of automatic temperature and humidity control will maintain the desired temperature and humidity

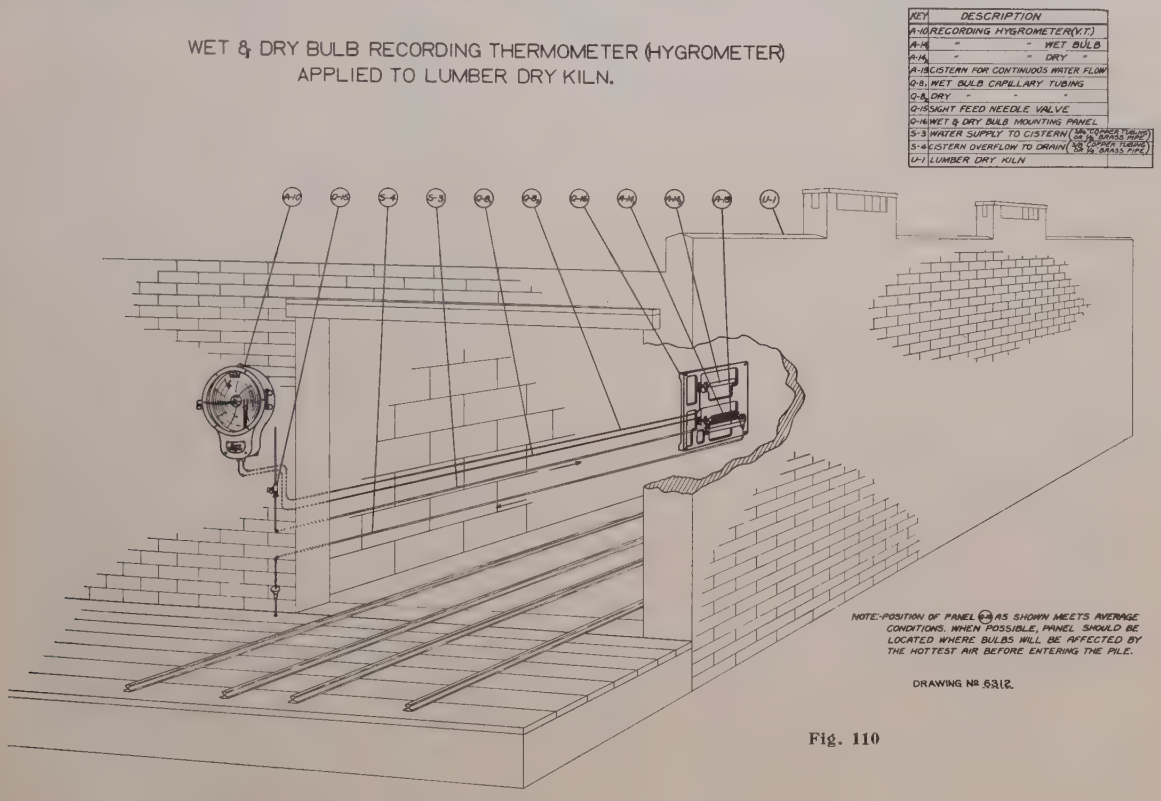

WET & DRY BULB RECORDING THERMOMETER (HYGROMETER) APPLIED TO LUMBER DRY KILN.
KEY DESCRIPTION
A-10 RECORDING HYGROMETER (V.T.)
A-14 " " WET BULB
A-14 " " DRY "
A-18 CISTERN FOR CONTINUOUS WATER FLOW
Q-8 WET BULB CAPILLARY TUBING
Q-8 DRY " "
Q-15 SIGHT FEED NEEDLE VALVE
Q-16 WET & DRY BULB MOUNTING PANEL
S-3 WATER SUPPLY TO CISTERN (¾" "COMMERCIAL" IRON OR ½ BRASS PIPE)
S-4 CISTERN OVERFLOW TO DRAIN (⅝ COPPER TUBING OR ½ BRASS PIPE)
U-1 LUMBER DRY KILN
NOTE:-POSITION OF PANEL (Q-16) AS SHOWN MEETS AVERAGE CONDITIONS. WHEN POSSIBLE, PANEL SHOULD BE LOCATED WHERE BULBS WILL BE AFFECTED BY THE HOTTEST AIR BEFORE ENTERING THE PILE.
DRAWING No. 6312.

Fig. 110

followed by a steaming or heating process which renders the staves more pliable. Complete assembly finally is accomplished by means of additional rings or hoops being driven on by special machines. The barrel is subjected to a final heating or firing, which serves to completely dry the staves and give them a permanent set. The insertion of the head is the final step in the assembly.

In order to make the barrels durable and efficient, they are coated inside with glue, which generally is put on in two operations. The desired amount of hot glue first is introduced in the kiln by means of a Direct-Set Recording Regulator (*Fig. 111, page 62*) in conjunction with air-operated diaphragm valves in the heating coils and spray lines. These valves are opened and closed automatically, to allow just enough steam to pass through them to keep the air in the kiln at the temperature and humidity desired. The Recording Hygrometer (*Fig. 112, page 62*) furnishes the operator a continuous check on the drying time and conditions.

Dry kilns should be equipped with

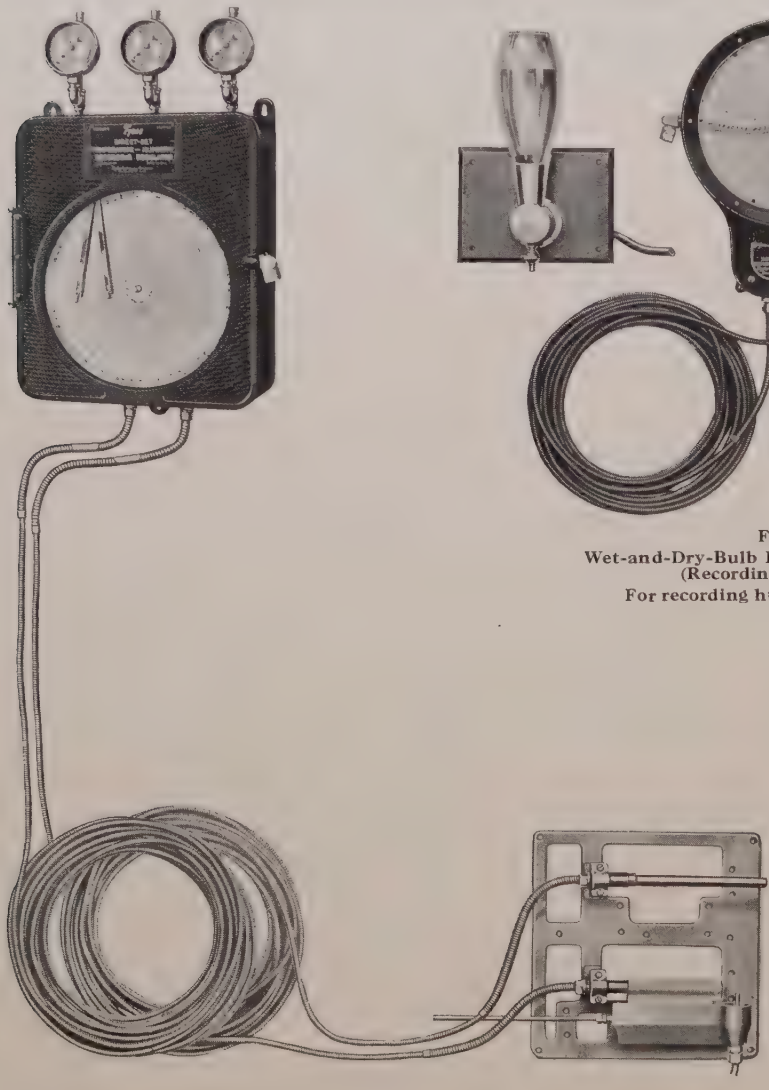


Fig. 111
Direct-Set Recording Regulator for Dry Kilns

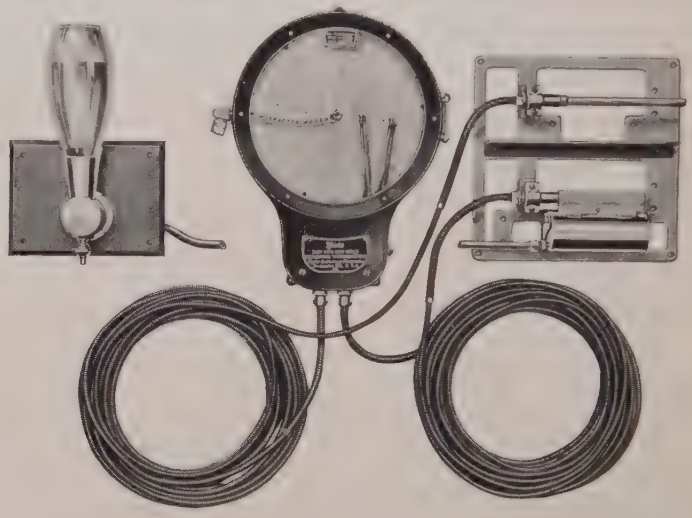


Fig. 112
Wet-and-Dry-Bulb Recording Thermometer
(Recording Hygrometer)
For recording humidity in dry kilns

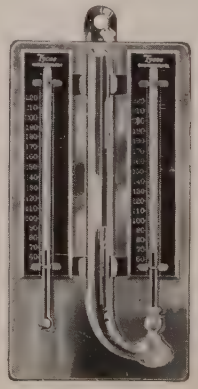


Fig. 113
Mason's
Wet-and-Dry Bulb
Hygrometer with
metal panel

through the bunghole and comes in contact with all of the interior surface by rolling the barrel. After an aging process, the barrel is given another coat of glue, which is set this time by means of a cold-air blast.

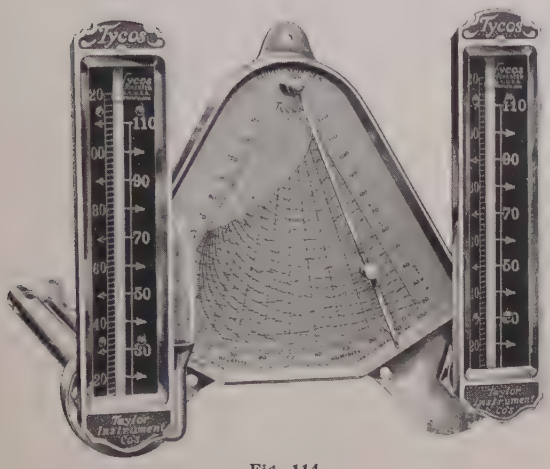


Fig. 114
Angle Hygrometer

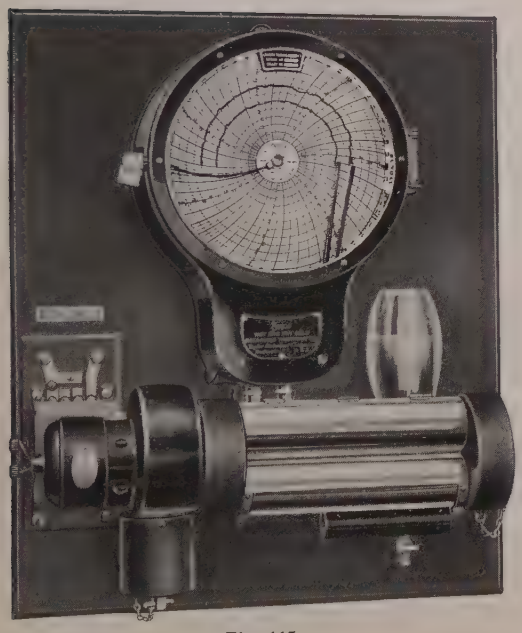


Fig. 115
Wet-and-Dry-Bulb Recording Thermometer
(Recording Hygrometer) with motor-driven fan

Recording Thermometers (*Fig. 18, page 10*) and Industrial Thermometers (*Figs. 24, 25, page 15*) for checking temperatures. The Angle Hygrometer (*Fig. 114, page 63*) also is used to advantage in kiln drying. This instrument consists of two angle thermometers with a dial mounted between them. The thermometer bulbs are inside the kiln, and the thermometer scales outside, thus allowing outside readings of humidity. The Sling Psychrometer (*Fig. 144, page 82*) also is used to advantage in showing humidities in dry kilns. This instrument is characterized by the facility with which tests can be made and the accuracy of the readings obtainable, as in whirling, the bulbs are subjected to perfect circulation.

HOT GLUE LINES AND GLUE KETTLES

Industrial Thermometers (*Figs. 24, 25, page 15*) and Recording Thermometers (*Fig. 18, page 10*) are applicable for showing temperatures in hot-glue lines. Temperatures in the glue kettle are controlled automatically by means of a Capillary-Type Temperature Regulator (*Fig. 69, page 41*) in connection with a diaphragm valve in the heating line. Industrial Thermometers (*Figs. 24, 25, page 15*) also are applicable in this system. Hydrometers (*Page 99*) are employed to show the gravity of the glue.

AIR HEATERS

Re-conditioning of barrels for second use generally is accomplished by a system of washing and steaming, followed by an air-drying process.

Air for drying purposes generally is preheated to a proper temperature by passage through an oven supplied with steam coils. The temperature of the air from these heaters can be controlled automatically by a Capillary-Type Regulator (*Fig. 69, page 41*) in connection with a diaphragm valve in the steam supply line. Index Thermometers (*Fig. 30, page 17*) Industrial Thermometers (*Figs. 24, 25, page 15*) and Recording Thermometers (*Fig. 18, page 10*) also are desirable for indicating and recording temperatures in this operation.

Can Manufacturing

Many refineries use tin cans quite extensively. Various size cans from one quart to ten gallons are standard containers for lubricants, naphthas and kerosine. Some concerns have sufficient requirements to justify their installing a special department for can manufacture.

The process for manufacturing cans is fairly simple and consists primarily of the following steps:—The body of the can first is cut to the required shape, then formed, and the seam pressed tight in a "horning" press. A special type of machine serves to securely attach the top and bottom to the body. All seams are rolled by machinery and then are ready for soldering.

Fig. 116
Molten-Metal Thermometer

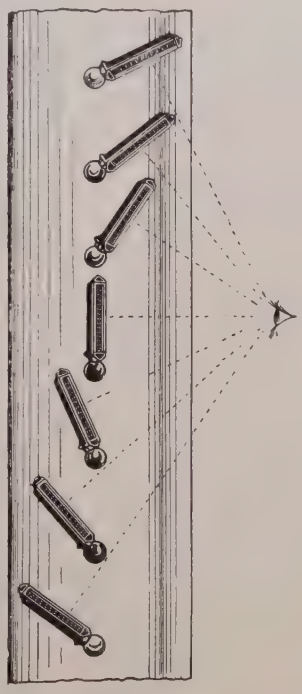
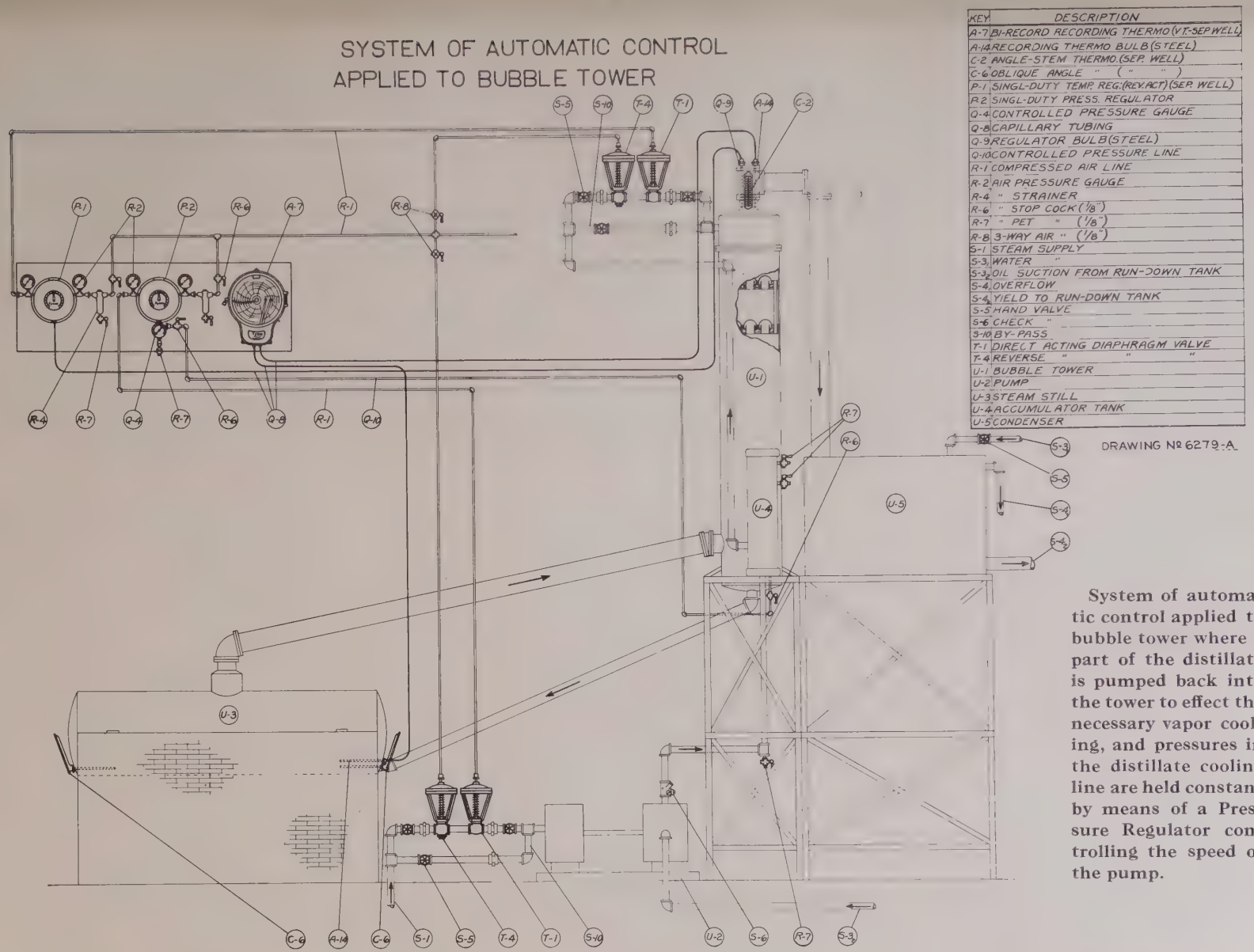


Fig. 117
Showing Application of Side-Angle Thermometers

Instruments Applicable in Can Manufacturing

In can manufacturing the temperatures in the solder bath can be controlled automatically by means of a Mercury-Actuated Temperature Regulator (*Fig. 48, page 25*) where gas or oil through a single-pipe burner is used as the heating medium. This control serves to regulate the fuel supply to the burner through the opening or closing of a diaphragm valve in the fuel supply line in accordance with the temperature desired in the bath. In electrically-heated systems automatic control can be applied to the solder-bath temperatures by means of the Electric-Contact Temperature Control (*Fig. 87, page 50*). This regulator in conjunction with a relay serves to open or close the heating circuit, dependent on the temperature desired. Industrial Thermometers (*Figs. 24, 25, page 15*) Index Thermometers (*Fig. 30, page 17*) and Recording Thermometers (*Fig. 18, page 10*) are applicable for clearly and accurately indicating and recording solder-bath temperatures.

Fig. 118
Recording Thermometer (Round-Case Type)


SYSTEM OF AUTOMATIC CONTROL
APPLIED TO BUBBLE TOWER
KEY DESCRIPTION
A-7 BI-RECORD RECORDING THERMO (V.T-SEP. WELL)
A-14 RECORDING THERMO BULB (STEEL)
C-2 ANGLE-STEM THERMO. (SEP. WELL)
C-6 OBLIQUE ANGLE " (" ")
P-1 SINGL-DUTY TEMP. REG. (REV. ACT) (SEP. WELL)
P-2 SINGL-DUTY PRESS. REGULATOR
Q-4 CONTROLLED PRESSURE GAUGE
Q-8 CAPILLARY TUBING
Q-9 REGULATOR BULB (STEEL)
Q-10 CONTROLLED PRESSURE LINE
R-1 COMPRESSED AIR LINE
R-2 AIR PRESSURE GAUGE
R-4 " STRAINER
R-6 " STOP COCK (1/8")
R-7 " PET " (1/8")
R-8 3-WAY AIR " (1/8")
S-1 STEAM SUPPLY
S-3 WATER "
S-3 OIL SUCTION FROM RUN-DOWN TANK
S-4 OVERFLOW
S-4 YIELD TO RUN-DOWN TANK
S-5 HAND VALVE
S-6 CHECK "
S-10 BY-PASS
T-1 DIRECT ACTING DIAPHRAGM VALVE
T-4 REVERSE " "
U-1 BUBBLE TOWER
U-2 PUMP
U-3 STEAM STILL
U-4 ACCUMULATOR TANK
U-5 CONDENSER
DRAWING Nº 6279-A

System of automatic control applied to bubble tower where a part of the distillate is pumped back into the tower to effect the necessary vapor cooling, and pressures in the distillate cooling line are held constant by means of a Pressure Regulator controlling the speed of the pump.

Fig. 119

The Manufacture of Natural-Gas Gasoline

The fact that natural gas sometimes contains gasoline vapors in varying quantities has led to the commercial utilization of this commodity as a basis for the manufacture of gasoline. The term "casing head" was applied originally to gasoline of this type, from the fact that the gas from which it was derived was obtained from the casing-head of oil wells. Natural gas which contains gasoline in quantities as high as one gallon or more per 1000 cubic feet of gas is known as "wet gas", while "dry gases" are those containing condensable gasoline in smaller proportions. The major part of natural-gas gasoline is produced from wet gases, but gasoline can be commercially extracted from natural gas containing as low as 0.1 gallon of gasoline per 1000 cubic feet. The importance of the natural-gas gasoline industry can be recognized from the fact that the volume now made is from 12 to 15 percent of the total gasoline produced.

Gasoline of this type, however, differs from ordinary straight-run gasoline, or gasoline from cracked petroleum distillates, primarily in its higher volatility. This naturally limits its use and gives rise to serious problems in connection with its transportation. In its broadest and most satisfactory application today natural-gas gasoline is used for blending with heavier distillates containing too-small amounts of the more volatile hydrocarbons, and through this practice much of the naphthas and other heavy ends are made available as satisfactory motor fuels.

The blending of naphtha or other petroleum products with natural-gas gasoline may be carried out at different stages in the gasoline manufacturing process. Many plants blend in special tanks known as "make tanks" where the oil is transferred from the accumulator tanks and the naphtha pumped in, or vice versa. In some cases blending is carried out in the accumulator tanks themselves, while in others the process is carried out in regular tank cars. Blending at present is carried out principally at the refineries.

There are two general methods now in use for the manufacture of natural-gas gasoline. These are (1) The Compression Process, and (2) The Absorption Process.

The Compression Process

The compression method is commercially applicable to wet gases, and the basic features of this process consist of the bringing about of a

The use of indicating and controlling instruments in natural-gas gasoline plants is recognized throughout the industry as a valuable aid in enabling the operator to determine and maintain the best conditions conducive to most efficient, economical and successful plant operation.

Industrial Thermometers (*Figs. 24, 25, page 15*) indicate the progress and condition of any operation, concretely and accurately expressed in terms of temperature. They enable the operator to determine and standardize on methods and processes experimentally demonstrated as most suitable to his needs. The Recording Thermometer (*Fig. 18, page 10*) furnishes a clear, accurate, and intelligible record of such conditions of temperature throughout an operation. It furnishes an absolute check on the efficiency of employees, apparatus and processes. It enables the operator to look back on yesterday's, last week's, last month's or last year's operation with a clear understanding and knowledge of detailed operations at any stage.

The application of automatic control has been one of the leading contributions to the high state of production efficiency which the natural-gas gasoline industry now enjoys. Their supreme importance is recognized through their vital relationship to uniformity and economy of production, and is attested to in a standard commodity, produced at a minimum expenditure of time, labor and power.

In an address on "Temperature and Control", delivered by Mr. A. F. Maxson at a district meeting of the National-Gas Gasoline Manufacturers, Shidler, Okla., he stressed the importance of thermometers and controls, the regular and frequent reading of these and other gauges, and pointed out that the neglect of controls might mean the loss of thousands of dollars to a plant in a year.

Indicating and controlling instruments find extensive and divergent application throughout the natural-gas gasoline industry. One of the larger mid-continent natural-gas gasoline plants,

condensation of gasoline vapors through a combination system of compression and cooling. This is accomplished in one or more stages of compression, dependent on the quality or richness of the raw gas with which the operator has to deal and the advantages attendent on each method of treatment. A typical procedure in the compression process as applied to a "rich" gas may be briefly outlined as follows:—

Gas obtained from the well either through flow induced by its own pressure or by vacuum, is transferred through a main gas line directly to the plant. In these lines drips are placed at intervals to collect and remove whatever portions of condensed gasoline and moisture may have formed, in addition to small amounts of crude oil that also may have been carried along. Before entering the compressors the gas usually is cooled to from 60° to 70°F. From the coolers it passes through a tank or "scrubber", which serves to remove the remaining liquids, dirt, or other suspended particles which might tend to impede the operation of the compressor.

In the first stage of a multi-stage compression treatment, the incoming gas may be compressed to about 40 to 60 lbs. resulting in a corresponding rise in temperature to about 200° to 250°F. The hot compressed gases are passed first through a separator to remove particles of oil which if present would tend to impair the color of the finished product, and then through cooling coils where condensation of the gasoline vapors takes place. Actual cooling at this stage may be accomplished by cold water sprayed over the coils or by the coils being submerged in a tank of water similar to the box-condenser.

Both the gas and condensate pass from the coolers to an accumulator, or low-pressure tank, where separation takes place. The condensate is removed by means of special traps, while the gas is piped to the compressor for the second compression treatment.

In the second stage of compression, the gas from the low-pressure tank may be compressed for example to 250 pounds, with an attendant rise in temperature. The process from here on is similar to that practiced where low compression is employed. The hot gases pass through the separator, thence to condensers and high-pressure accumulator tanks, where the gas and condensate are separated as before.

operating at a daily production of 15,000 gallons of gasoline from 1,500,000 cubic feet of gas, has so standardized systems by use of labor-saving devices that the entire production is carried on by four men per shift. Thermostatic controls on stills and knock-out boxes are a prominent factor in this accomplishment.

In the application of air-operated automatic controls in natural-gas gasoline plants it is practically universal custom to use the natural gas itself as the motive force for operating the controls. This is aided by the installation of the necessary reducing valves to bring the pressure to the amount required.

Instruments Applicable to Compression Plants

COMPRESSOR LINES

Since the factor of pressure is a fundamental element in the manufacture of natural-gas gasoline, a knowledge of pressures and temperatures existing in gas inlet and outlet compressor lines is at all times necessary in order to keep a check on the efficiency of the compression process. Recording Thermometers (*Fig. 18, page 10*) and Recording Pressure Gauges (*Fig. 19, page 11*) are used in compression plants for furnishing continuous records of temperatures and pressures in gas inlet and outlet lines.

The combined Recording Thermometer and Pressure Gauge (*Fig. 56, page 29*) shows on a single chart corresponding records of both temperature and pressure.

Industrial Thermometers (*Figs. 24, 25, page 15*) are specially applicable and widely used for indicating temperatures in the gas-outlet and water-outlet lines. (*Fig. 120, page 68*) shows an actual installation of Industrial Thermometers in compressor discharge lines at one of the larger mid-continent natural-gas gasoline plants.

The Direct-Acting Pressure Regulator (*Fig. 62, page 35*) will maintain constant pressure in the outlet gas line, by regulating the speed of the steam-driven compressor, by means of a diaphragm valve in the steam supply line.

Fig. 120
Industrial Thermometers on Compressor Discharge Lines in a Natural-Gas Gasoline Plant.

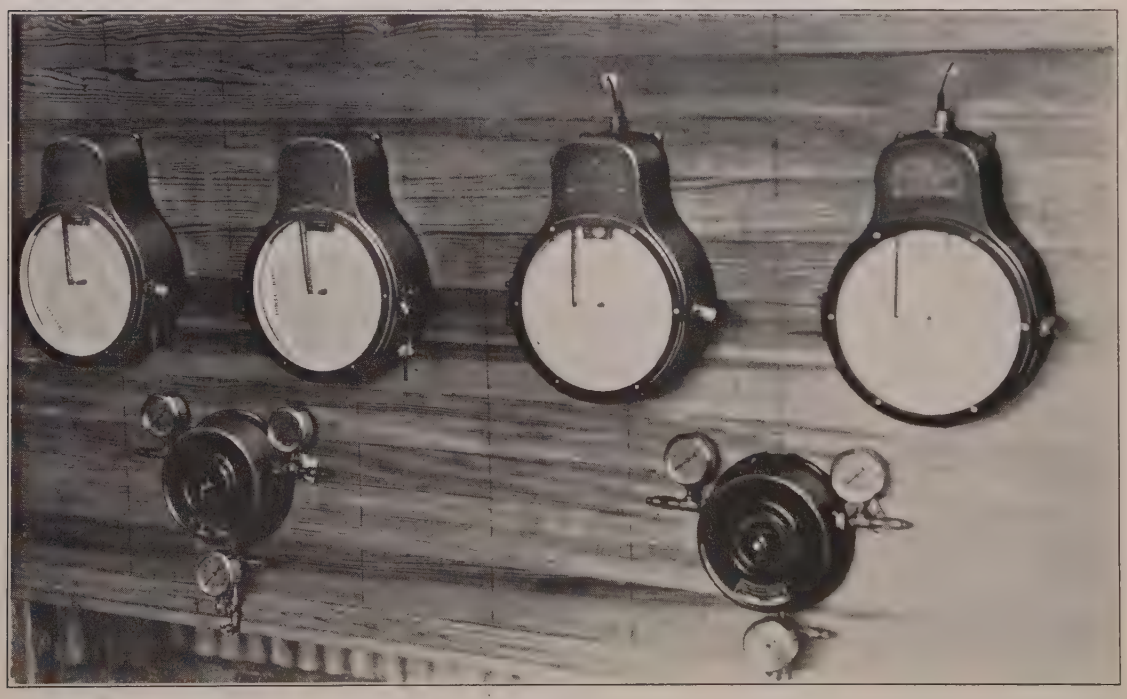


Fig. 121
Instrument Panel-Board under construction in a Natural-Gas Gasoline Plant, showing Recording Thermometers, Recording Pressure Gauges, and Pressure Regulators.

The Absorption Process

The absorption method of extracting gasoline from natural gas is based on the relative solubility of gasoline vapors in liquid hydrocarbons. This process is particularly adaptable to the so-called "lean gas", or the gases which are poor in gasoline content, but at the present time various modifications have made its use practicable for both rich and lean gases. The essential points in connection with absorption systems consist in bringing the gas into intimate contact, or mixing with the absorbent oil and transferring the solution to an evaporator or still, where the gasoline vapors are driven off and condensed.

An absorbent commonly used is that known as "mineral seal oil". This is a heavy distillate characterized by its high boiling point, low viscosity and a high solvent power for gasoline. Other oils are sometimes used, such as gas oil and occasionally naphthas.

Absorbers

In the operation of a typical absorption plant the incoming gas to the plant may previously be subjected to a compression treatment, cooled to the necessary condition, and passed through special baffles or traps, to remove undesirable materials, such as lubricating oils and moisture, or quantities of gasoline. From the traps it passes to the absorption towers, where it enters at the bottom and is intimately mixed with the cold incoming absorption oil, in counter-current flow from the top of the tower. Intimate contact is here aided by the special design and construction of the tower itself. A common form of absorber is the packed tower. Tower packing may consist of different materials, ranging from wooden grids to steel cuttings placed in such definite arrangement as to present a maximum surface exposed to the liquid and at the same time provide a maximum free space.

Another form of absorber is the bubble type, in which the incoming rich gas is forced to bubble through the absorbent oil maintained in a series of compartments or trays in the absorber.

The gas, freed of its gasoline content, emerges from the top of the absorber and is disposed of as fuel. When absorption has been carried out under high pressures the rich saturated solution of oil and gasoline passes from the bottom of the absorber into a vent tank where the pressure is considerably reduced, with the accompanying release of a large volume of gas comprising the lighter dissolved constituents. From here the rich solution

COOLING LINES

Industrial Thermometers (*Figs. 24, 25, page 15*) are applicable for indicating temperatures of the gas and condensate from cooling coils, thereby indicating the efficiency of the cooling process.

ACCUMULATOR TANKS

A Reverse-Acting Pressure Regulator (*Fig. 62, page 35*) in conjunction with a Direct-Acting Diaphragm Valve (*Fig. 52, page 27*) in the gas discharge line will automatically maintain constant back pressures in the accumulator tank, or on the compression unit. This instrument serves as a pressure relief valve to release from the accumulator tank any pressure in excess of that for which the instrument is set. From the nature of the operation of the control, the regulator valve is instantaneously responsive to the slightest change in pressure on the system under control.

When this installation is applied to high-pressure tanks, it may be found advisable to provide around the diaphragm valve a housing effect, through which a small steam or heating line can be run, to provide warmth to prevent "freezing" or "sticking" of the control valve, which effect might come about as a result of the expansion of the gas on reduction from extremely high to low pressures.

Recording Pressure Gauges (*Fig. 19, page 11*) will show clear, accurate, and continuous records of pressures existing in accumulator tanks.

Instruments Applicable to Absorption Plants

Temperature is a determining factor in the efficiency of the gasoline extraction process. Its influence is reflected in the capacity of the absorption oil, the nature of the recovered hydrocarbons, and the volume of the raw gas treated by the process itself. Pressure is likewise a predominating influence in its relation to volume, flow, and saturation of the absorbent.

ABSORBERS

The Reverse-Acting Pressure Regulator (*Fig. 62, page 35*) will automatically maintain constant back-pressures in absorbers. This instrument, in conjunction with a Direct-Acting Diaphragm valve (*Fig. 52, page 27*) in the dry-gas line

passes to another vent tank, where the pressure may be reduced to practically atmospheric conditions, with the attendant release of another quantity of gas. The gases here recovered may be used directly as fuel.

The recovery of the gasoline from the absorption oil is the next stage in absorption-plant operations. In a plant cycle the rich absorption oil is pumped through heat exchangers, where it undergoes a preliminary heat treatment through indirect contact with the hot residual oil from the still. Heat Exchangers may be of different design or construction, but the principle of operation is based on the counter-current flow of the cooler medium through chambers containing the hotter circulating oil. Heat Exchangers are not only important units in natural-gas gasoline plants, but they are of extreme importance in all refinery operations where it is possible to utilize waste heat to advantage.

Heat Exchangers

The lean absorption oil from the heat exchangers undergoes a further and final cooling and is ready for recycling through the absorber. The rich gasoline-oil solution from the exchangers is sometimes next conveyed to Preheaters, where it is subjected to a further increase in temperature. The Preheater somewhat resembles the heat exchanger in general features of construction, but heating is accomplished in the system by means of steam.

Preheaters

Final and complete separation and recovery of the natural-gas gasoline vapors is in many cases accomplished through continuous steam distillation of the gasoline-oil mixture in special Stills or Evaporators, or by the use of continuous topping apparatus, such as a pipe-still and evaporator. The distillation equipment is of primary importance in an absorption plant and ranks with the absorber as a fundamental and essential unit in plant construction and operation. Stills of a number of different types have been installed in gasoline plants and many are of the same general characteristics as those used in refineries for somewhat similar distillation operations. Some operators use the ordinary horizontal shell-type steam still, or the shell-type still equipped with a special tower through which the incoming oil-gasoline solution is charged to the still itself. The horizontal pan-type of still is employed to some extent, the oil in this case entering the still in a small stream, coming into contact with closed steam-heated coils as it flows from a series of inclined pans to the bottom of the still, where it

Stills or Evaporators

from the absorber, acts as a pressure relief valve to release from the unit pressures in excess of those desired. The control itself is instantaneously responsive to the slightest change in pressure.

HEAT EXCHANGERS

Heat Exchangers in absorption plants result in conservation of heat and fuel, and materially reduce the amount of water required for cooling and the amount lost by evaporation. Industrial Thermometers (*Figs. 24, 25, page 15*) are applicable for showing temperatures in heat-exchanger lines, thereby giving an indication of the efficiency of the heat transfer. Recording Thermometers (*Fig. 18, page 10*) are applicable for showing a continuous record of temperatures in heat-exchanger lines, and Bi-Record Recording Thermometers (*Fig. 93, page 54*) will show on a single chart corresponding records of temperatures of both the rich absorption oil and lean absorption oil on entering and leaving the exchangers.

PREHEATERS

The rich absorption oil in its passage through the heat exchangers is heated as high as 170°F. In the preheaters, sufficient steam is employed to further raise and maintain this temperature at the desired point. The Temperature Regulator (*Fig. 69, page 41*) will automatically control temperatures in the preheater when steam from one source is used, by means of a diaphragm valve in the steam supply line. The Double-Duty Temperature Regulator (*Fig. 109, page 60*) will control temperatures when both live and exhaust steam are used in a similar manner as applied for temperature control in steam stills. Industrial Thermometers (*Figs. 24, 25, page 15*) and Recording Thermometers (*Fig. 18, page 10*) are recommended for indicating and recording temperatures in preheaters.

STILLS

In no phase of gasoline plant operation is the need for temperature indicating and controlling devices more urgent and apparent than in the still. Quoting further from Mr. Maxson, "A high still temperature will overload the knock-out box and result in high end-point and possibly off-color gasoline. A low still temperature results in improper stripping of the oil and low production".

is heated directly by steam, in open or closed coils, or a combination of the two. Vertical-type Stills or Evaporators of different design and construction also are coming into wide use. One type is characterized by an inner series of trays or baffles, which aids the separation of gasoline from the oil by a system of agitation, as the oil-gasoline mixture falls to the bottom of the still. This part of the still is equipped with an open steam-coil submerged under the proper oil level for steam distillation purposes.

Fig. 122
Actual Size of Upper Part of 9″ and 12″ Industrial Thermometer Scale-Case

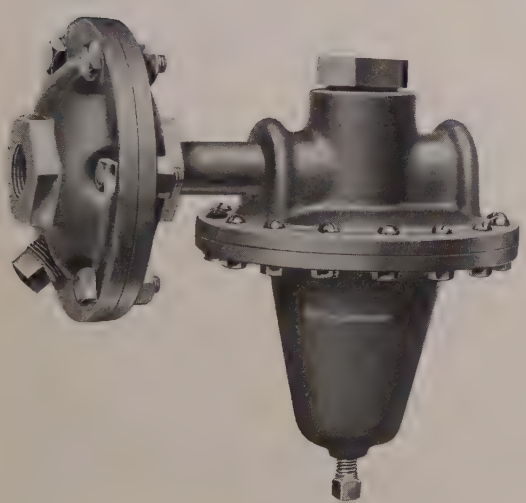


Fig. 123
Reducing Valve for reducing air or gas pressure to 25 lbs., for operating Temperature or Pressure Regulators

Industrial Thermometers (*Figs. 24, 25, page 15*) are furnished in styles most convenient for clearly and accurately showing still temperatures in pipe or drum stills, or in the vapor lines from the stills. Temperature Regulators (*Fig. 69, page 41*) control still temperatures in steam or gas-fired stills, by regulating the fuel, through a diaphragm valve in the fuel supply line. Many operators use the Expansion-Stem-Type Temperature Regulator (*Fig. 128, page 74*) in this connection, and (*Fig. 125, page 72*) shows a typical application in one of the larger mid-continent gasoline plants. The Double-Duty Unit-System Temperature Regulator (*Fig. 51, page 27*) controls temperatures in steam stills where both live and exhaust steam are used as the heating medium. This regulator connected to two diaphragm valves, one in the exhaust- and one in the live-steam line, permits the necessary amount of exhaust steam to be used and when heat from this source becomes insufficient, automatically opens the live-steam line until the desired temperature has been reached. Recording Thermometers (*Fig. 18, page 10*) are necessary adjuncts in the System of Automatic Control for stills and are extensively used both in this connection and independently for recording temperatures in absorption-plant stills and vapor lines. (*Fig. 124, page 72*) shows an application of Recording Thermometers on steam stills in a natural-gas gasoline plant.

The Direct-Set Recording Regulator (*Fig. 72, page 43*) is applicable for recording and controlling temperatures in steam-or gas-fired stills in natural-gas gasoline plant operations. This instrument combines in one case a recording thermometer and an air-operated temperature regulator with the direct-set feature.

The Direct-Set Indicating Regulator (*Fig. 72½, page 43*) is applicable likewise for indicating and controlling temperatures in steam or gas-fired stills. This instrument combines in one case an index thermometer and an air-operated temperature regulator with the direct-set feature.

Fig. 124
Recording Thermometers on Steam Stills in Natural-Gas Gasoline Plant

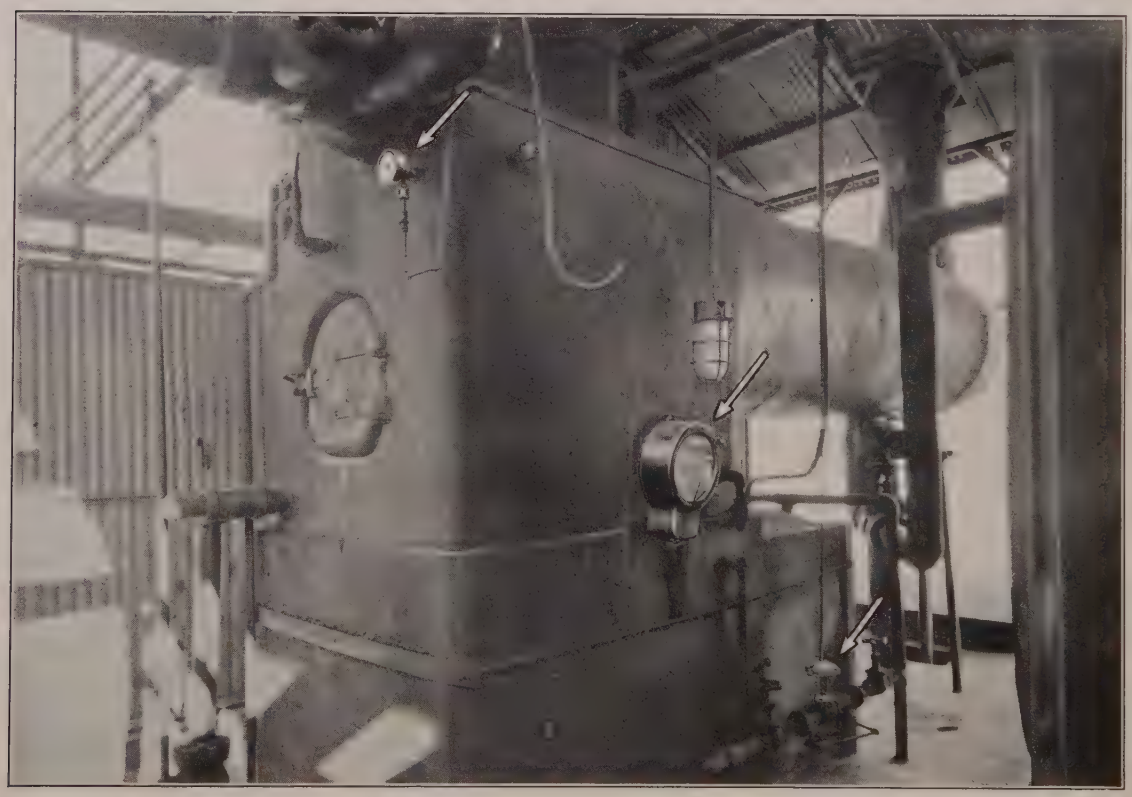


Fig. 125
Expansion-Stem-Type Temperature Regulator and Diaphragm Valve Controlling the Temperature, and Recording Thermometer Recording the Temperature in a Gas-Fired Still at a Natural-Gas Gasoline Plant

Merriam Process Plants

The Merriam Process of gasoline recovery accomplishes distillation without the aid of steam. The rich absorption oil here is continuously introduced into the end of a long narrow horizontal still heated throughout its length by gas burners, the oil gradually attaining a higher temperature as it traverses the length of the still. Distillation is materially aided by a special arrangement whereby the vapors previously evolved from the rich absorption oil as it passes through the heat exchangers, are separated and continuously introduced below the surface of the oil at the outlet end of the still. These vapors sweep over the oil as they traverse the length of the still and enter the rectifying column at the opposite end.

From the still the stripped absorption oil finds its way through the heat exchangers and final coolers and then to the absorbers.

Knockout Box or Dephlegmator

The gasoline vapors separated from the absorption oil by steam distillation processes are mixed with steam from the still and small amounts of the absorption oil itself, probably present both as a vapor and as minute particles of liquid held in mechanical suspension. The separation of the gasoline vapors from this mixture is sometimes accomplished by passing the combined vapors through a preliminary cooler known as a Knockout Box, Dephlegmator, or primary condenser. Temperatures in the Knock out-Box are maintained around 180° by the proper admission of cooling water through the coils. Most of the water vapor, together with the heavier gasoline fractions, is condensed here and trapped off with the quantities of absorbent oil similarly collected, while the remaining vapors and lighter gases pass to the final water-cooled condensers.

The tubular type of primary condenser, or the dephlegmator, is essentially a fractionating column somewhat similar in purpose and

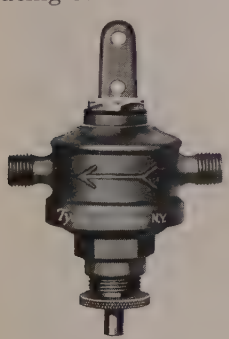


Fig. 126
Air Reducing Valve

Fig. 127
Air-Pressure Gauge

MERRIAM PROCESS PLANTS

In Merriam Process Plants, Capillary-Type Temperature Regulators (*Fig. 69, page 41*) are applicable to single-pipe oil or gas-fired stills for automatically effecting still temperature control by throttling the supply of fuel to the burner. This is accomplished in conjunction with a diaphragm valve in the fuel supply line.

The Expansion-Stem-Type Regulator (*Fig. 128, page 74*) is likewise applicable for effecting such control.

Industrial Thermometers (*Figs. 24,25, page 15*) and Recording Thermometers (*Fig. 18, page 10*) are recommended for indicating and recording still temperatures.

DEPHLEGMATORS, OR KNOCKOUT BOXES

Dephlegmator or knockout-box temperatures in the gasoline industry are of the same essential importance as tower temperatures in refinery distillations, for temperatures as here carried determine the color, gravity and end-point of the gasoline produced. Excessively high temperatures at this point mean an "off color" gasoline of higher end-point than the specified limit. A successful marketing of this product will necessitate a re-run, with consequent distillation loss, interference of plant routine, and additional expenditure of time, labor and power.

Excessively low temperatures in the dephlegmator result in a condensation of valuable products at this stage, with the consequent reduction of the plant output. Whenever the gasoline vapors knocked down in the dephlegmator find their way back to the main circuit of the lean absorption oil, there results a diminution in the absorption capacity of the oil for the gasoline in the rich field gas, with an attendant loss of production.

The Capillary-Type Temperature Regulator (*Fig. 69, page 41*) in conjunction with a diaphragm valve in the cooling supply line will automatically control dephlegmator or knock-out-box temperatures by the proper admission of the cooling medium through the valve. With the bulb (sensitive member) of the regulator in the outlet vapor line from the dephlegmator, a rise in temperature of the vapors is immediately reflected in the closing of an air-port in the instrument, releasing air from the diaphragm valve,

general features of construction to the dephlegmator in ordinary refinery distillation practices. The degree of efficiency of fractionation and the quality of the recovered gasoline are determined by the temperatures of the vapors leaving the dephlegmator.

Temperatures are here controlled by the circulation of the cooling medium through coils near the top of the tower, or by an open discharge of the cooling medium into the tower. Various systems employ either the cold rich absorption oil, cold water, or a part of the gasoline itself for cooling purposes.

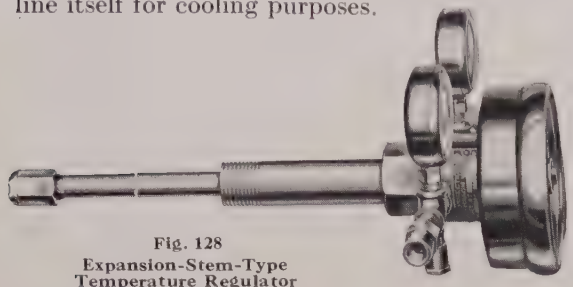


Fig. 128
Expansion-Stem-Type Temperature Regulator Showing Extension Neck

thus admitting the cooling medium to compensate for the change in temperature in the vapor line. A fall in temperature of the vapors leaving the dephlegmator, in like manner reacts against the air-port in the instrument to admit air to close the diaphragm valve, shutting off the cooling-medium supply.

A feature of the above scheme of control, which is characteristic of air-operated instruments, is the ability to secure a throttling action of the diaphragm valve. The supply of cooling medium is throttled down by a partial

Fig. 129
Expansion-Stem-Type Temperature Regulator Showing Union Connection

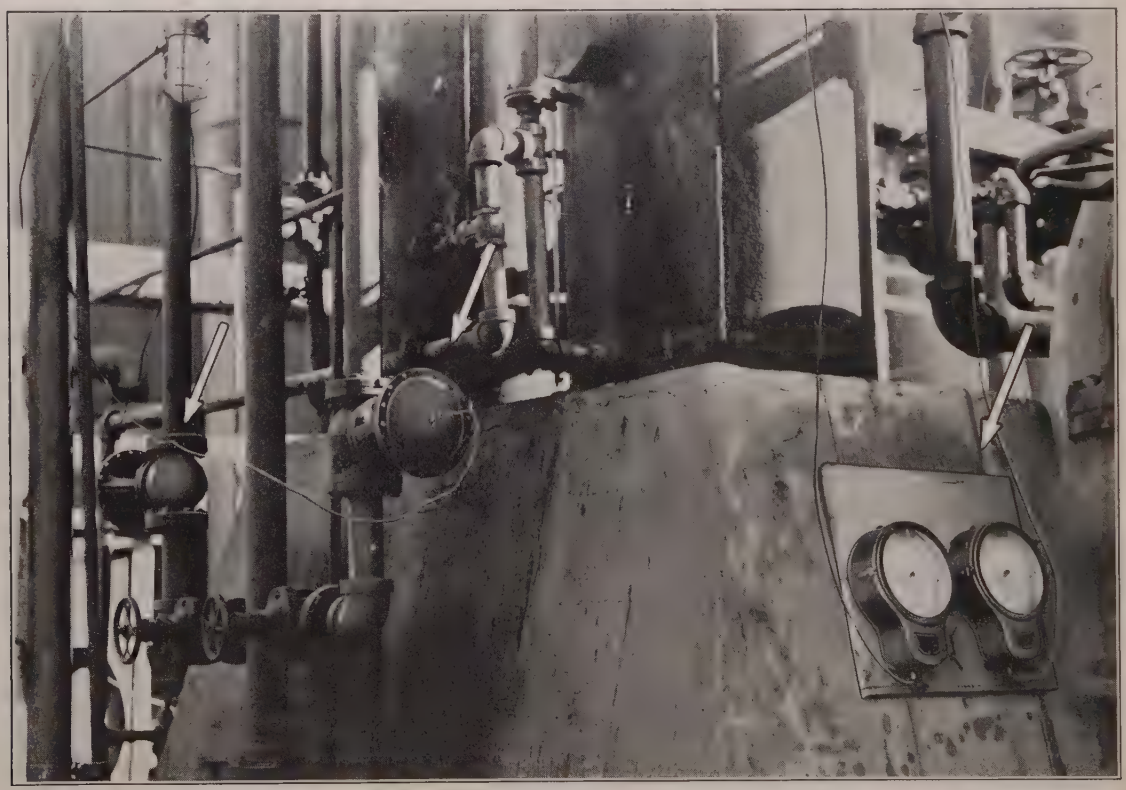


Fig. 130
System of Automatic Control applied to Knockout Boxes or Dephlegmators in a Natural-Gas Gasoline Plant. The arrows at the left indicate the diaphragm valves which work in conjunction with Expansion-Stem-Type Temperature Regulators, controlling the temperature of the operation. An Expansion-Stem-Type Regulator is located in the vapor-outlet line at the top of each tower, but these do not show in the picture. The arrow at the right indicates panel board on which are mounted two Recording Thermometers, recording the temperature maintained by the regulators. The recorder bulbs are located in the vapor-outlet line of each tower.

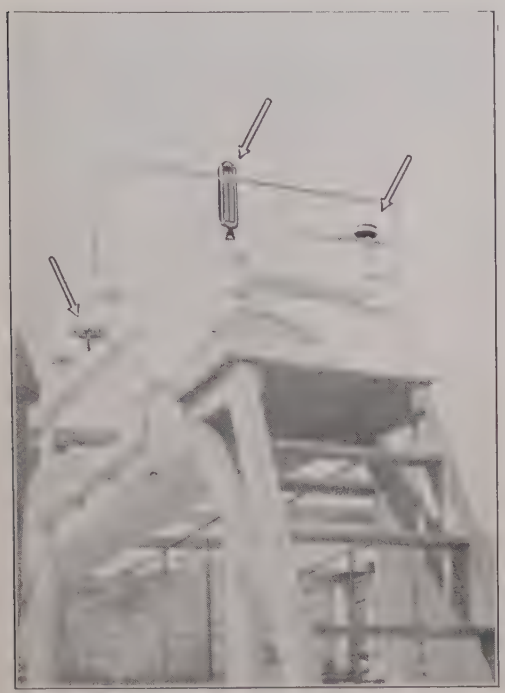


Fig. 131
Close-up of Gilmore Conserving Condenser, showing Expansion-Stem-Type Temperature Regulator, Diaphragm Valve and Industrial Thermometer, properly installed.

Fig. 132
Shows Tower of Gilmore Conserving Condenser. Arrows indicate location of instruments.

opening of the valve to whatever flow the conditions in the vapor line require, and is not regulated through full opening or closing of the valve, as is the case with many types of controls.

A further treatise on this type of installation involving the additional application of the Recording Thermometer is given previously under the head of "Automatic Control for Bubble Towers" (*page 39*).

Recording Thermometers (*Fig. 18, page 10*) are used extensively in gasoline plants for recording dephlegmator temperatures, both when such temperatures are regulated automatically and by hand.

In many cases of dephlegmator-temperature regulation, operators prefer the Expansion-Stem-Type Temperature Regulator (*Fig. 129, page 74*) for automatically effecting such control. The principle of operation of this instrument is based on the expansion or contraction of a metal stem, under the influence of heat or cold. This movement is reflected against an air-port in the instrument to release the pressure supply actuating the diaphragm valve.

In the fundamental principles and accuracies of regulation, these instruments function as satisfactorily as Capillary-Type Temperature Regulators (*Fig. 69, page 41*). The fact, however, that the dial of the instrument can be located only immediately adjacent to the point of application of the stem makes this installation less desirable than the Capillary-Type Temperature Regulator, (*Fig. 69, page 41*) which can be located as far as 75 feet from the point of application of the sensitive member.

The Direct-Set Recording Regulator (*Fig. 72, page 43*) is a combination recording thermometer and control, which is coming to be widely used in connection with the operation of dephlegmators, or knockout boxes. This intrument combines in one case a recording thermometer and an air-operated temperature regulator with the direct-set feature. The recorder furnishes a record of the temperature of the vapors leaving the knockout box, and therefore acts as a check on the regulator.

The heavier gasoline and oil portions condensed during the fractionation of vapors drain back into the bottom of the dephlegmator as reflux and are usually reprocessed by mixing with the rich absorption oil.

Condensers

The clarified gasoline and remaining water vapor condensed in the final water-cooled condensers are separated by gravity, the gasoline being run through look boxes to storage, the water being discharged to waste. Uncondensed vapors remaining at this stage are sometimes further processed by systems of compression and condensation, with the compression treatment being carried out in one or more stages, as desired. The different condensates separately collected are then combined. The uncondensed gases finally remaining are termed fixed gases and usually are mixed with dry gases from the vent tanks and disposed of as fuel.

Fig. 133
Round-Case Recording Pressure Gauge

Fig. 134
Pressure Regulator
(Air or Gas Operated)
For maintaining constant back pressures in natural-gas gasoline plants

Fig. 135
Straight-Stem Industrial Thermometer

The Direct-Set Indicating Regulator (*Fig. 72½, page 43*) combining in one case an indicating thermometer and an air-operated temperature regulator with the direct-set feature, is applicable to knock-out boxes.

CONDENSERS

The maintenance of proper temperatures in water-cooled condensers is necessary to the complete recovery of the gasoline vapors and the reduction to a minimum of the uncondensed gases. Unduly high temperatures in a condenser will result in the loss of valuable gasoline constituents, or will necessitate additional systems of compression and cooling for their complete recovery. In U. S. Bureau of Mines Technical Paper 310, by D. B. Dow, on "The Recovery of Gasoline from Uncondensed Still Vapors", it was pointed out that the losses in gasoline resulting from non-condensation of still vapors is astonishingly large. Quoting from Mr. Dow, "As shown previously, certain factors are responsible for the non-condensation of gasoline vapors, and the question arises whether in attempts to reduce the loss it will be more economical to change plants already built than to install plants for recovering the vapors as gasoline. A recovery plant is in reality a secondary condensing system, an auxiliary to the primary condensers. This means that if temperatures of the gas from the condensers could be kept low enough the recovery plant would be of small advantage. Maintenance of a low temperature in the gas stream, however, depends on cold water and a large condenser area."

In no phase of gasoline recovery is the above factor of more importance than in natural-gas gasoline plants.

The Temperature Regulator (*Fig. 69, page 41*) will automatically maintain proper temperatures in water-cooled condensers of either the box or the closed type, by regulating the flow of the cooling water through a diaphragm valve in the cooling line. Industrial Thermometers (*Figs. 24, 25, page 15*) and Recording Thermometers (*Fig. 18, page 10*) are especially desirable for condenser temperature applications.

Water-Cooling Apparatus

In many cases of refinery or gasoline plant operations a scarcity of cool water makes it necessary to re-cool and re-use water for the condensing or cooling process. Water cooling is accomplished generally by spraying the water, as evidenced in the "spray ponds", or by cooling towers.

Stabilizing Processes

Natural-gas gasoline produced by the absorption as well as the compression process is highly volatile, or "wild", due to the presence of the gaseous hydrocarbons absorbed in the liquid gasoline and the constant tendency of these lighter materials to evaporate. The removal of these constituents is necessary to produce a stable gasoline suitable for transportation and otherwise of commercial desirability and importance. This was formerly accomplished by the process of "weathering" in which the gasoline was allowed to stand in low-pressure tanks until the more volatile constituents had evaporated. The generally unsatisfactory results of this method, due to the loss of valuable gasoline products, led to the development of the stabilizer, which is an important factor in connection with the successful operation of a gasoline plant. Stabilizing processes are directed towards the maximum recovery of a superior grade of gasoline.

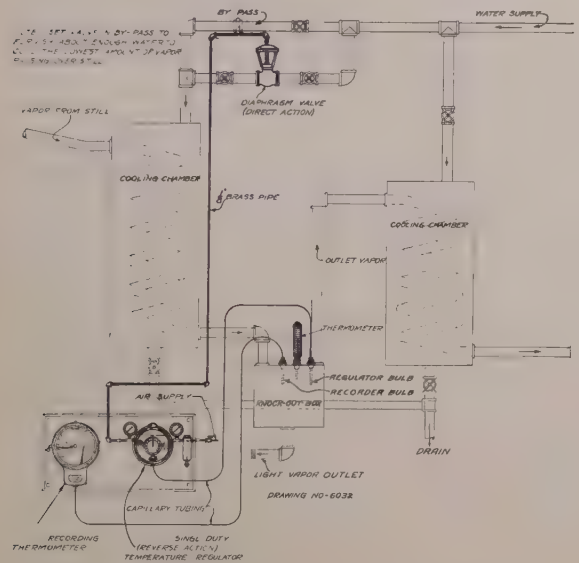


Fig. 136

Temperature Regulator and Recording Thermometer Controlling and Recording Temperature of Oil Vapors in Knock-Out-Box by regulating the flow of cooling water

Water-Cooling Apparatus

Industrial Thermometers (*Figs. 24, 25, page 15*) and Recording Thermometers (*Fig. 18, page 10*) are recommended for temperature application, in the water supply line from the water-cooling apparatus.

Stabilizing Processes

Industrial Thermometers, Recording Thermometers, and Temperature Regulators are applicable in stabilizing processes, for indicating, recording and controlling temperatures where such measurements and control are necessary or desirable. Pressure Regulators also are applicable for controlling back pressures.

Fig. 137

Union-Connection Hub with ¾" Pipe Thread

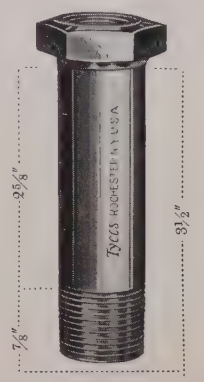


Fig. 138

Union-Connection Hub with ¾" Pipe Thread and 2⅝" extension-neck between wrench-head and thread

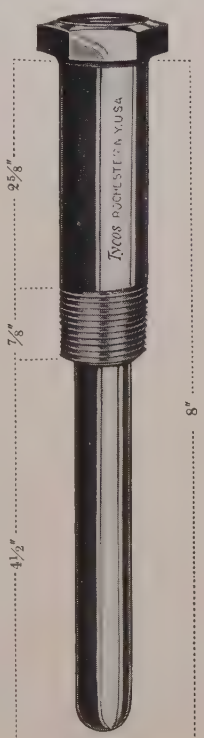


Fig. 139

Separable Well with ¾" Pipe Thread and 2⅝" Extension Neck between wrench-head and thread

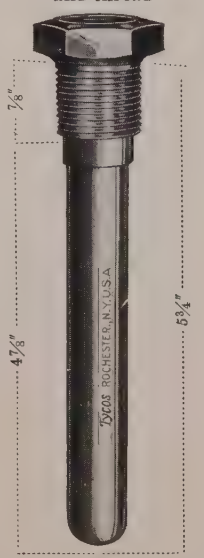


Fig. 140

Separable Well with ¾" Pipe Thread

Gilmore Conserving Condenser

The Gilmore Conserving Condenser is a gasoline-plant unit designed for the production of high-grade natural-gas gasoline. Quoting from a pamphlet furnished by the Forest E. Gilmore Company, the operation is as follows: "The vapor from the still or the gas from the low-stage compressor passes through a cooler, where it is cooled by water, the resulting temperature being controlled by thermostatic regulation of the water to the cooler. The vapors or gases, cooled to the desired temperature, are discharged together with any contained condensate into the bottom of a special fractionating tower. The vapors or gases move upward through the descending gasoline and after giving up about all of the heavy contained gasoline, pass out to the suction of the recompressor or to the high stage compressor of the compression plant. These compressed gases are cooled and the condensate is collected in the usual accumulator tank, while the gases escape through a relief valve into the residue gas lines".

"All the condensate in the accumulator tank is then injected into the top of the tower. Since this is mostly butane, with some propane, it boils at a temperature below the freezing point, and when introduced into the top of the tower, which is under reduced pressure, it immediately begins to boil, cooling itself by this boiling or evaporation as it descends. The resulting cold liquid flows down in the tower over special trays holding large quantities of it in the tower, where it comes in close contact

Instruments Applicable to the Gilmore Conserving Condenser

The efficiency of the Gilmore Conserving Condenser is in part dependent on the proper cooling of the gasoline vapors from the still, or gases from the compressor, as they pass through the cooler previous to their entrance to the fractionating tower. Temperatures are here controlled through a regulation of the supply of water to the cooler. The Expansion-Stem-Type Temperature Regulator (*Fig. 129, page 74*) has been used extensively and successfully in the operation of the Gilmore Conserving Condenser, for automatically effecting such control. This regulator in conjunction with a diaphragm valve in the cooling-water supply line, automatically regulates the admission of water to the cooler in accordance with the temperature desired in the outgoing vapor line. Industrial Thermometers (*Figs. 24, 25, page 15*) are correspondingly used for indicating temperatures of the vapor leaving the cooler. (*Figs. 131, 132, page 75*) show an actual installation of the above System of Automatic Control on a Gilmore Conserving Condenser in a natural-gas gasoline plant. These show clearly the natural compactness of arrangement of the regulator, diaphragm valve, and industrial thermometer, the essential units of the control (*see also Fig. 141, page 78*).

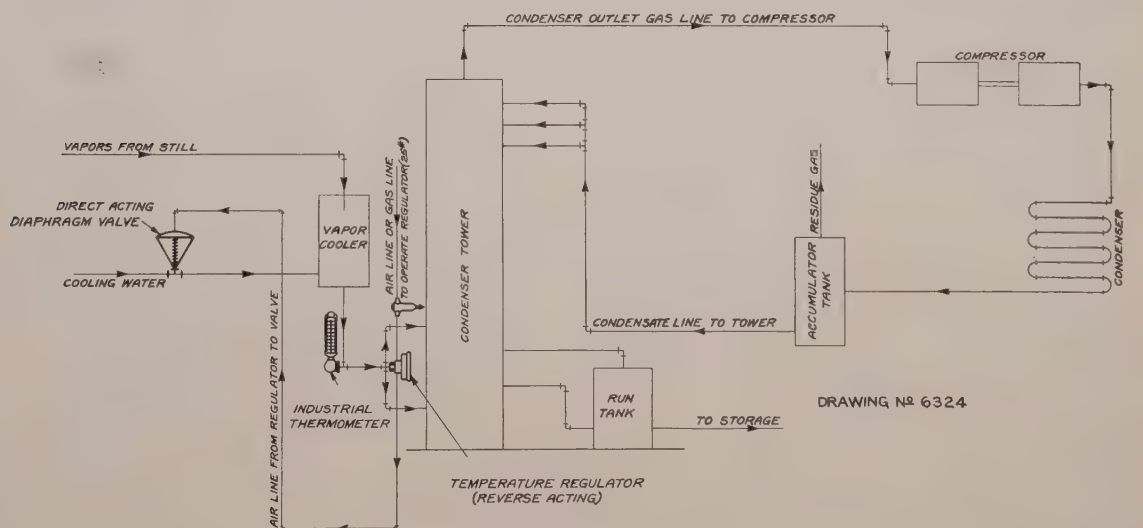


Fig. 141

Indicating and Controlling Instruments Applied to Gilmore Conserving Condenser

with the rising vapors or gases. These vapors or gases are cooled until they condense or are absorbed in the extremely cold liquid near the top of the tower. The condensing process is so gradual that the heavy constituents of the contained gasoline are first condensed at relatively high temperatures and are dropped from the rising vapors or gas without any opportunity to absorb any of the propane gases. The condensate introduced in the top of the tower from the accumulator tank is so thoroughly weathered, agitated and warmed in its descent through the tower to the finished gasoline at the bottom, that all the dissolved gases are eliminated."

The Charcoal Absorption Process

Where natural gas containing gasoline vapors comes in contact with activated charcoal, the gasoline is absorbed by the charcoal, while the lighter or fixed gaseous constituents remain unaffected. This fact has led to the commercial utilization of this product in gasoline extraction. The charcoal absorption process is a fairly recent development, although quite a number of operators have adopted it. The primary units of a charcoal absorption plant consist of absorbers, steam boilers, condensers, and storage tanks. In general operation several absorbers are installed and serve to function both as absorbers and stills. They are usually vertically constructed, ranging from 25 to 35 feet in heighth, and three or more feet in diameter, and are packed with fine granular activated charcoal. Natural gas passes through each absorber in turn. When the first has reached the absorption limit the gas supply is switched to the second tower, while live steam is turned into the first, the gasoline being distilled off and condensed. When the second tower has reached its capacity, the gas is switched to the third tower, while the gasoline is distilled from the second. The charcoal in the first tower is cooled by the residue gas from the second or third towers.

The gas then passes through cooling coils previous to its being discharged to the main gas line.

In the steaming out of a unit to drive off the gasoline, the method of fractionation does not differ materially from that of any other type of plant. The combined vapors pass first through the primary cooler, where condensation of the water vapors takes place, and then through the final water-cooled condensers for the recovery of the gasoline. Uncondensed vapors and gases here remaining may be then subjected to a compression treatment for a more complete recovery of the desired product.

Instruments Applicable to Charcoal Absorption Plants

Industrial Thermometers, Recording Thermometers, Recording Pressure Gauges and Temperature and Pressure Regulators are applicable in Charcoal Absorption Plants for indicating, recording, and controlling operating conditions of temperature and pressure in a manner as previously described under the Compression Process and the Absorption Process for the manufacture of gasoline.

Capillary-Type Temperature Regulators (*Fig. 69, page 41*) or Expansion-Stem-Type Temperature Regulators (*Fig. 129, page 74*) will automatically maintain constant temperatures in the vapor line from the dephlegmator or primary cooler, by regulating the supply of cooling medium to the apparatus, as previously described under "knockout boxes" or "dephlegmators". In like manner these instruments will automatically control gas temperatures from the gas coolers, or temperatures in the final condensers, by regulating the flow of the cooling agent.

Recording Thermometers (*Fig. 18, page 10*) are applicable for recording temperatures in the vapor lines from the absorbers, thereby providing an invaluable record of the changes that occur in the operation of the Charcoal Absorption Plant. A complete cycle of absorber operations is clearly traced in a manner easily read and interpreted. These instruments show the time, extent, and regularity of the temperatures and temperature changes, factors which in themselves are fundamental evidences of the efficiency of plant procedure.

Concerning the application of the Recording Thermometer in Charcoal Absorption Plants, Oberfell and Alden in "Natural Gasoline" state: "The 'Policeman'-chart records the temperatures of the vapors leaving the absorbers. By means of it the speed and regularity of the changes are made a permanent record and the faithfulness of plant operators to their duties is unmistakably subject to the scrutiny of the plant superintendent."

№	DESCRIPTION
1	COMPRESSOR
2	RECORDING PRESSURE GAUGE
3	RECORDING THERMOMETER
4	INDUSTRIAL THERMO.(ANGLE STEM)
5	COOLER OR CONDENSER
6	ACCUMULATOR TANK
7	PRESSURE REGULATOR(R.A.)
8	DIAPHRAGM VALVE(D.A.)
9	GASOLINE STORAGE TANK
10	ABSORBER
11	VENT TANK
12	HEAT EXCHANGER
13	STILL
14	TYPE "P" TEMPERATURE REG.(D.A.)
15	TOWER, KNOCK-OUT BOX OR DEPHLEGMATOR
16	SINGL-DUTY TEMP. REGULATOR(R.A.)
17	CONDENSER
18	SEPARATOR TANK
19	OIL COOLING COILS
20	SEPARATOR
21	INDUSTRIAL THERMO.(STRAIGHT STEM)
22	AIR OR GAS LINE TO OPERATE REGULATOR

INDICATING, RECORDING & CONTROLLING INSTRUMENTS APPLIED TO NATURAL GAS GASOLINE COMPRESSION & ABSORPTION SYSTEMS

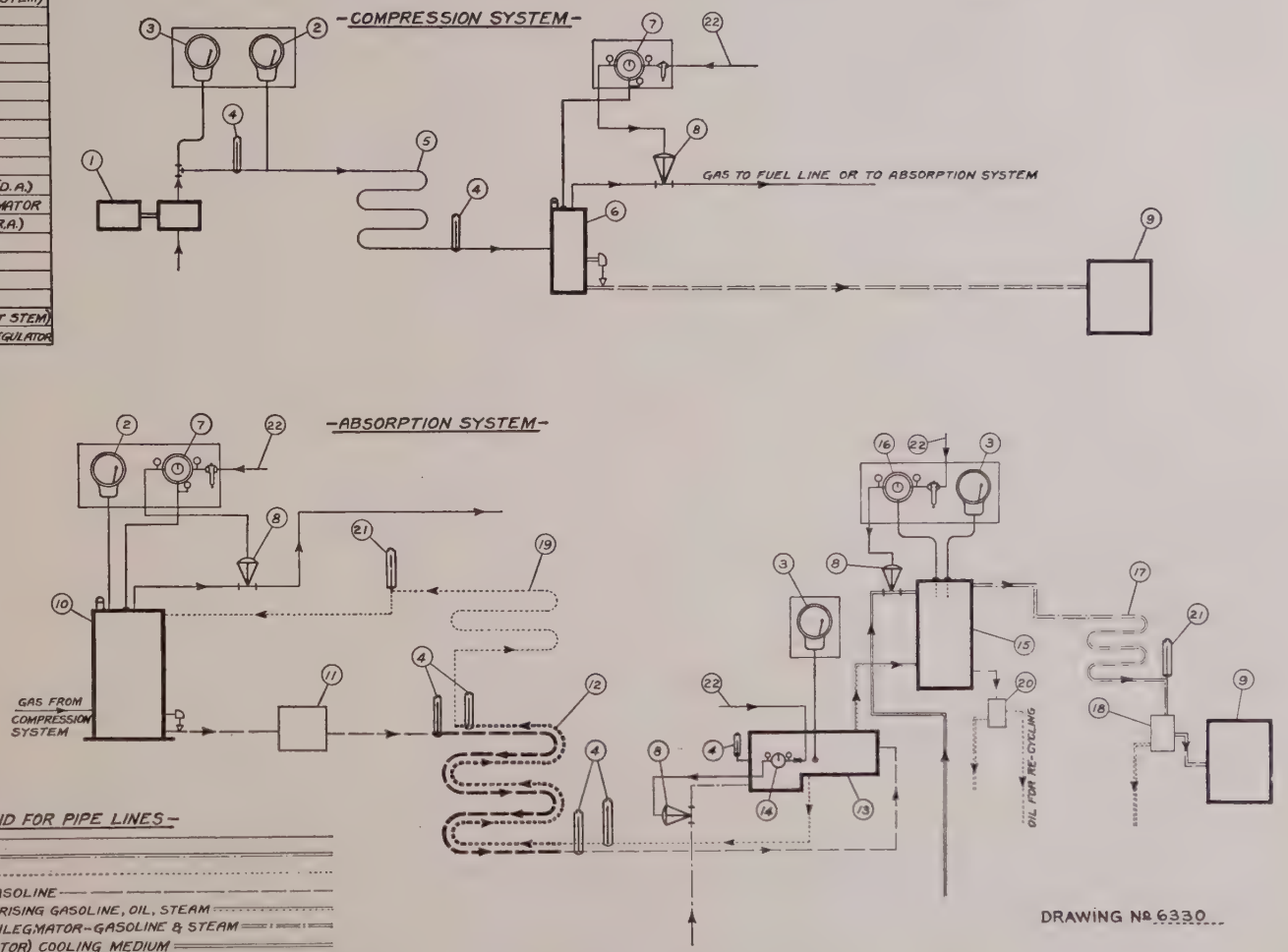


Fig. 141½

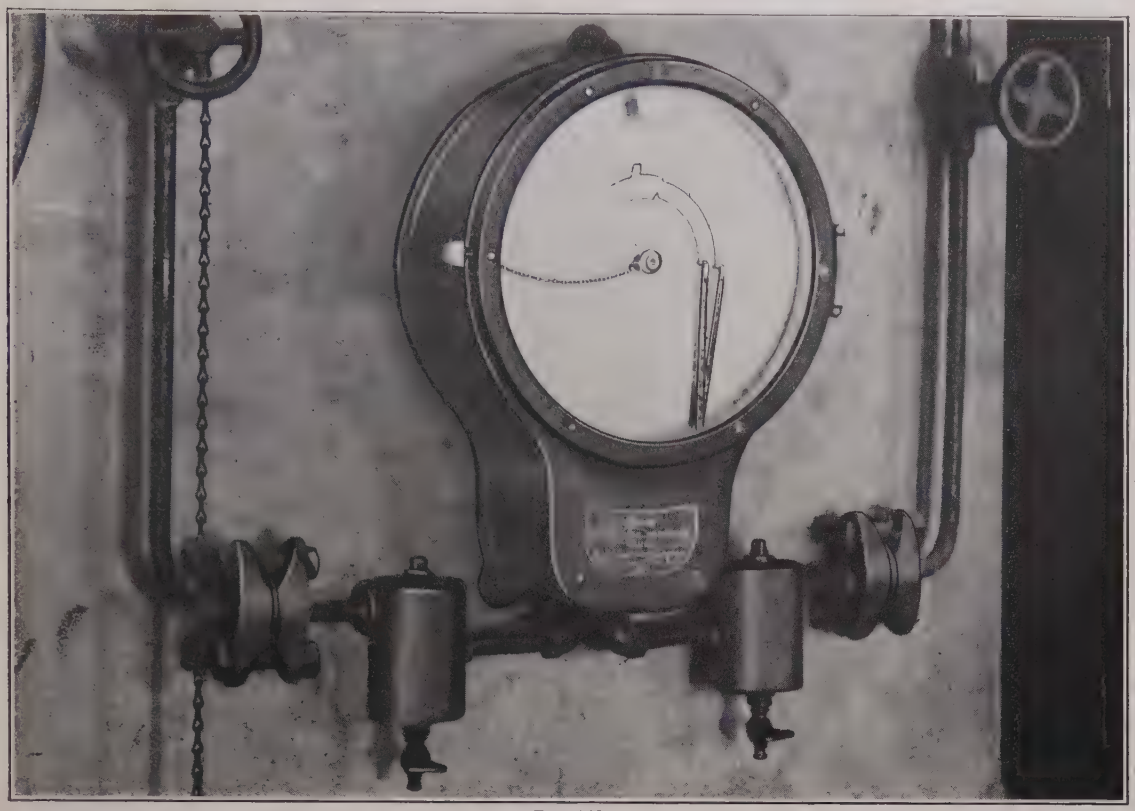


Fig. 142
Double-Record Recording Pressure Gauge on Suction and Discharge Ammonia Gas Pressures on an Electric-Driven Refrigeration Machine

Fig. 143
Photograph of Instrument Board in Large Steam-Power Plant

Steam Power Plants in the Oil-Refining Industry

The steam power plant is one of the most important and essential units of an oil refinery, as evidenced by the wide-spread use of steam in practically all phases of refining, both in process work and in the generation of mechanical power. In complete refineries where both the light and heavy distillates are separated and refined, the amount of steam used in the stills and in wax, filter, and compounding plants is astonishingly large. In skimming plants a much smaller quantity suffices. Bell, in his treatise "American Petroleum Refining" estimates the daily steam requirements of a 1500 bbl. complete refinery to be around 750,000 lbs., or the equivalent of about 1,042 boiler horsepower. In natural-gas gasoline plants requisites are of no less importance than in other phases of refining, although the application here is more limited.

The application of instruments in steam power plants is varied and extensive. A special catalog is obtainable showing a complete selection of instruments proven from years of experience to best meet the requirements of the various applications. The selection of proper instruments for specific applications is simplified by an index which gives the various steps in regular sequence, and the points of application themselves are further clarified by reference to a chart showing a complete diagrammatic layout of a power plant, with points for application of instruments shown thereon.

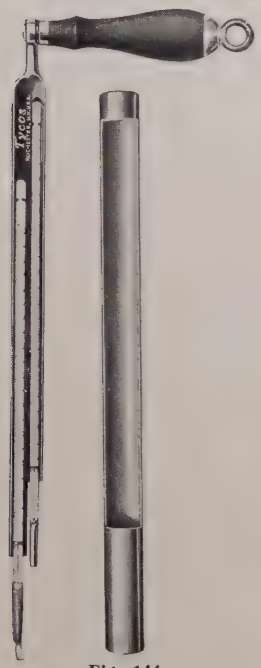


Fig. 144
Sling Psychrometer

Fig. 145
Pocket Draft Gauge

Fig. 146
Direct-Reading Superheat Indicator

Fig. 147
Angle Thermometer with long stem for installation through wall

Fig. 148
Left Side-Angle Thermometer

Fig. 150
Anemometer

Fig. 149
Engine-Room Barometer

Fig. 151
Recording Pressure Gauge

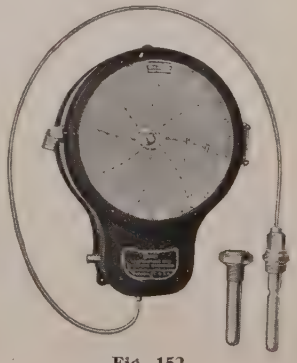


Fig. 152
Combined Recording Gauge and Thermometer

Part 2

(*For Index, see page 190*)

Covering the more common laboratory practices, or tests, applied to crude petroleum and its different refined components; and a short treatise on some of the instruments used in laboratory practice.

Tests of Petroleum Products

No petroleum product can be definitely classified by a single physical or chemical test. In every case it requires several tests to definitely define the individual product and its suitability to the use for which it is required.

The following paragraphs give a general outline of the tests that are employed in the analysis of petroleum products, and the properties of the materials that are indicated by each.

No attempt is made to give in detail the method of procedure in performing these tests, but where they have been standardized by the American Society for Testing Materials reference is made to the proper standard or tentative standard test number.

Complete copies of these standards can be obtained from the American Society for Testing Materials, 1315 Spruce Street, Philadelphia, Pa.

As the reliability of any test depends primarily upon the accuracy of the instruments employed and the suitability and design of the apparatus in general, care should be taken to see that the equipment used in performing the test is correct in design and accurate in its indications.

GRAVITY

Gravity, as the term is here used, is derived from Specific Gravity and is the weight of a material compared with the weight of an equal volume of water at a standard temperature. This value is expressed in either Specific Gravity or degrees A.P.I. The corresponding values for these scales are found in tables beginning on pages 113 and 109 respectively. A knowledge of the gravity of a petroleum product is important to the producer or the refiner as an index to the proper classification of the material being tested, or the source from which it was derived.

In testing crude petroleum the gravity gives an indication of the light-oil content and, therefore, its comparative value as a source for motor fuels.

In gasoline the gravity in relation to the figures for the distillation range assists in determining the presence of aromatic hydrocarbons.

In lubricating oils the gravity assists in identifying the type of crude from which the material is derived.

As all liquid petroleum products are sold by volume, in the marketing of these materials it is essential that the gravity be determined with a high degree of accuracy. As the volume figures are obtained by taking the weight and the gravity of the material, the corresponding pound per gallon or gallons per pound to the gravity is found in tables beginning on pages 113 and 109 respectively.

The gravity of liquid petroleum products can most conveniently and accurately be determined with a hydrometer. The readings can be taken at atmospheric or existing temperatures in the material and these readings converted to true gravity at a temperature of 60°F., by reference to tables beginning on pages 115 and 134 respectively.

In determining the gravity of an oil it is essential not only to have an accurately-scaled hydrometer, but it is further necessary to obtain an accurate temperature reading, as the high coefficient of expansion of petroleum products causes a considerable change in the gravity readings with the rise or fall of temperature above that of standardization. More data on hydrometers will be found on pages 99 and 100.

Where the available sample is so small that it is impossible to test it with a hydrometer the Specific Gravity bottle with drilled stopper generally is employed. In this case the actual weight of a given volume of oil and water are determined under definite conditions of temperature. The weight of the oil is divided by the weight of the water, giving the Specific Gravity of the oil. To control the temperature properly the necessary volume measurements are made in a thermostatic bath.

The Westphal Balance consisting of an immersed sinker of known weight and volume at a standard temperature, is also sometimes used, the difference in the weight of the sinker in air and immersed in the liquid being tested, or the buoyant effect of the liquid on the sinker indicating its gravity.

The gravity of solid or semi-solid petroleum products is determined either by heating them until they are sufficiently liquid to make it possible to employ one of the methods described above, or the weight of a given volume of the solid is compared with the weight of an equal volume of water at a standard temperature, from which determination the gravity of the material can be calculated.

Another method of determining gravity of solid petroleum products is to mould the material into a suitable form and immerse this body in a cylinder of water. If the material floats add alcohol to the water until the sample neither floats nor sinks. If the sample sinks when immersed in water add sodium chloride solution to the water until the sample comes to a position where it

neither floats nor sinks. The sample is then removed and the gravity of the liquid in the cylinder is taken with a hydrometer; this gravity being recorded as the gravity of sample.

DISTILLATION

The distillation test shows the percentages of petroleum products that will vaporize at certain temperatures. Fractional distillation is the fundamental process in the refining of petroleum and this same procedure carried on under laboratory methods is the basis of a number of analytical methods applicable to many of the products. The analytical distillation of petroleum products is commonly made to determine the range of boiling point, or to separate the material into fractions for detailed examination.

In the examination of crude petroleum, while the distillation method applied to gasoline and kerosine may be used to obtain approximate results, the condition of the material in this apparatus is so greatly different from that in the actual refining method employed industrially that it is not highly satisfactory for this work. The best results can be obtained only by using an apparatus that is a miniature design of the commercial type of installation, but of a size to adapt it to laboratory operation.

In distilling crude petroleum the light-oil fractions are driven off at atmospheric pressure. The separation of the heavier fractions can be done without cracking, either by steam or under a partial vacuum. The application of excessive heat tends to break up the different fractions or, as it is termed, "crack" the oil. As the different fractions are determined and classified by the temperature readings, it is of the highest importance that thermometers used in this test should be not only of assured accuracy but also of the proper type, this of course applying to all distillation tests.

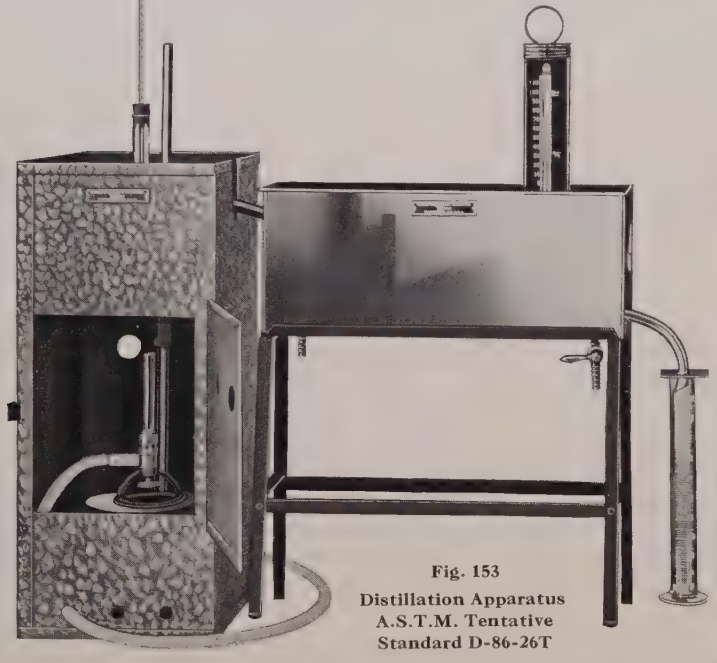


Fig. 153
Distillation Apparatus
A.S.T.M. Tentative
Standard D-86-26T

The presence of any appreciable amount of water in crude petroleum makes the analytical distillation of the sample difficult and the results unreliable. The sample therefore should be dehydrated, a common method being to heat the sample in a suitable container with some dehydrating agent, such as calcium chloride, which has no chemical reaction on and is not appreciably soluble in the oil. As the boiling point varies with atmospheric pressure, for close analytical distillation, correction should be made to a standard reference table (*page 185*). The terms "initial" which is the temperature as indicated by the thermometer when the first drop of condensed liquid falls from the end of the condenser column, and "end point" which is the highest temperature reading observed on the thermometer before the temperature curve falls slightly before again rising, are used to define the extremes of the individual fraction.

The distillation test of gasoline, A.S.T.M. Tentative Standard D-216-25T for Natural-Gas Gasoline and A.S.T.M. Tentative Standard D-86-26T for Gasoline, Naphtha, etc., shows some of the most valuable information regarding the products that can be obtained. The low-temperature end of the distillation indicates the presence of a sufficient quantity of low-boiling constituents to permit ready starting of a cold motor and yet not a large enough amount of such products to cause excessive evaporation losses or make it dangerous to handle. The high-temperature end must be governed to give suitable volatilizing conditions at the operating temperature of the motor and yet not exceed the limit of the vaporizing power of the engine, or to allow for unburned materials being left in the cylinders.

The fact that the most efficient type of motor fuel varies not only with the type of engine in which it is to be used, but also with the conditions under which the engine is to be operated makes the distillation test one of the most important, as it indicates quite generally the character of the material. The distillation test on kerosine, or burning oil, A.S.T.M. Tentative Standard D-86-26-T, indicates the suitability of the material for the required use. There should not be enough volatile material in these oils to make them dangerous under ordinary handling conditions, nor should there be present high boiling-point constituents that will impair the burning qualities of the oil.

The distillation test of gas oil, by showing the range of volatile material is a valuable indication of its quality and adaptability to certain uses.

COLOR

The color test of petroleum products is a comparison with standard color solutions or glasses. The range of color may be from clear water-white to opaque black. As applied to crude petroleum the terms are black, brownish-black, brown, reddish-brown, greenish-brown, green and brownish-green.

A common method of determining the color of crude is to compare the color of a sample strongly diluted with colorless benzol, with that of a standard iodine solution.

The color of gasoline serves as an index to other qualities, the more highly-refined products being practically colorless, or water-white.

The color of burning oil ranges from water-white to straw and serves as an indication of the removal of objectionable products, such as unsaturated hydrocarbons.

Color determination of gasoline and burning oil, A.S.T.M. Tentative Standard D-156-23T, is made by the chromometer, in which the color number is based on the height of the sample liquid measured in a standard tube, compared with standardized colored glasses.

The colors of lubricating oils, A.S.T.M. Tentative Standard D-155-23T, are of great value not only in classifying the material, but also in indicating the condition of same. In reflected light these oils show a fluorescence, or bloom, which varies materially with relation to the crude from which the material is produced, or the treatment it has undergone in refining.

Color determinations are, therefore, taken by transmitted light, which eliminates this fluorescence and gives a more definite color comparison with the standard color glasses used.

The color of petrolatum, A.S.T.M. Tentative Standard D-218-25T, is determined in a similar manner to lubricating oil.

The coloring matter in petroleum oils consists of very complex unsaturated hydrocarbons, which decompose under heat or when exposed to oxidization. Oxidization not only changes the bloom but also darkens the color of the oil. Oils which contain moisture become cloudy in appearance and even opaque, and appear to be darker than when dry.

ODOR

The odor test of petroleum products is a more-or-less arbitrary value, and indicates primarily some of the processes to which it has been subjected or the admixture of other materials. A burnt or pungent odor indicates destructive distillation, or cracking, while the so-called sweet or pleasant odor indicates fractional or uncracked distillation.

Where petroleum products are mixed with fixed oils, or other materials, a noticeable characteristic odor of such products may indicate the composition.

Petroleum products for domestic use, such as gasoline, burning oils, medicinal oils and petroleum jellies and waxes, should be either odorless or free from disagreeable odors.

WATER AND SEDIMENT (B.S.)

The term "B.S." is commonly applied to emulsions of oil and water, although in its broader sense it applies to oils or emulsions containing sand, carbonaceous or asphaltic matter, iron rust, scale, etc. The presence of both this material and water in crude petroleum is a detriment, as it not only increases the viscosity, but also has a tendency to clog pipe lines. The presence of water is dangerous in oils, as it will turn to steam on heating and tends to drive the material through the vapor lines or overrun the stills.

The presence of water in petroleum products is determined by A.S.T.M. Standard D-95-24, for crude petroleum, fuel oil, gas oil and road oil. This consists of distilling a sample of the material in a special apparatus and collecting in a special graduated container the water driven off therefrom.

A.S.T.M. Standard D-96-24 may also be used, which employs a centrifuge and specially-designed graduated glass tubes containing 100 cc of the sample, the water and sediment being deposited at the bottom of the tubes and measured.

A simple method of detecting the presence of water or moisture in oils having a flash test sufficiently high so they will not ignite, is to heat an iron rod to redness and slowly immerse it in the oil. If there is more than a trace of water present the tiny particles of moisture will suddenly turn into steam with a crackling noise.

VISCOSITY

The viscosity, or body, of a petroleum product may be said to express the lack of fluidity of the material, or that property—its internal friction—which resists any force tending to produce flow. As in the case of gravity determination, the temperature at which the test is made is very important, as the viscosity of all petroleum products decreases, in some of them very rapidly, with increasing temperature.

In testing crude petroleum viscosity is not only an indication of quality but also is a measure of the behavior of the oil through pipe lines under definite conditions.

In testing burning oils it is an indication of the feeding qualities through wicks.

The method of determining the viscosity of these products is by determining the time required for a definite rise in a standardized glass capillary at a standard temperature.

The viscosity of lubricating oils, A.S.T.M. Standard D-88-26, is one of the most important properties of the material, as it almost directly indicates the general condition and possible behavior of the oil under actual conditions of use.

The viscosity of fuel oils, A.S.T.M. Standard D-88-26, is a direct indication of the action of the oil in pipe-lines and also a factor in determining the necessary treatment to insure proper atomization in the burner.

In foreign countries different instruments are considered standard, the Redwood Viscosimeter both for lubricating oil and fuel oil being the standard in England, and the Engler Viscosimeter standard in a number of the continental countries.

Values determined on one type of viscosimeter can be converted to corresponding values on other types.

SULPHUR

The presence of certain sulphur compounds in petroleum products is detrimental and they are treated therefore to remove such material. The test on motor fuels, illuminating oils and naphthas, A.S.T.M. Tentative Standard D-90-26-T, is made by burning a sample of the oil under definite conditions in a special lamp, the products of combustion being passed into a measured amount of standard sodium carbonate solution and the excess titrated with standard hydrochloric acid solution. In testing heavier petroleum products such as crude petroleum, fuel oil, etc., A.S.T.M. Tentative Standard D-129-22-T, the oxygen bomb apparatus is employed. For determining sulphur in gas oil, either of the above methods may be used.

CARBON RESIDUE

The application of this test to reduced crude is an aid in determining whether or not it will yield a good grade of lubricating stock, one of the important requirements of which is comparative freedom from asphaltic or pitchy constituents. The results obtained by the carbon-residue test agree closely with known facts regarding the behavior of various types of crude and the usual processes of refining. In carrying out the carbon-residue test on crude the residue from the laboratory distillation of the crude is weighed out into a special container, heat is applied, at first gently, and finally vigorously, until the bottom of the crucible is red hot. The amount of carbon residue is determined by cooling and weighing.

Determination of carbon residue in lubricating oils, which during use are vaporized or burned, as is the case in internal-combustion engines, is of great value, as such oils should be as nearly free of such material as is possible. It is of course necessary for such oils to have the slightest possible tendency to carbonize as this action will cause the deposit of solid material which is very objectionable.

The carbon residue test for lubricating oils, A.S.T.M. Tentative Standard D-189-24T, consists in general of heating a small sample of the material in a special apparatus, properly controlling the temperature until all the volatile matter is driven out, after which the residue is cooled and weighed.

CLOUD AND POUR POINTS (COLD TEST)

The method for this test is A.S.T.M. Tentative Standard D-97-25-T which contains the following definition:

The cloud point of a petroleum oil is that temperature at which paraffin wax, or other solid substances begin to crystallize out, or separate from solution, when the oil is chilled under definite specified conditions.

The pour point of a petroleum oil is the lowest temperature at which the oil will pour or flow when it is chilled without disturbance under certain definite specified conditions.

The test for cloud point should be used only for oils which are transparent in layers 1½″ thick.

The test for pour point should be used for all other petroleum oils, and may be used for oils on which the test for cloud point is permitted.

A knowledge of the temperature at which an oil becomes semi-fluid or solid is essential not only in handling the product but in determining its suitability for certain uses.

In crude petroleum it is of importance in showing whether the oil will flow properly in pipe lines, etc.

In illuminating oil it is essential that under low temperature conditions it will not reach a state where it will not flow properly through the wick.

In lubricating oils that are exposed to low temperatures it is of extreme importance to know that they will not thicken to a point where they either lose their lubricating value thru failure to flow properly thru feed lines or tend to retard the motion of the surfaces they are supposed to lubricate.

DOCTOR

The doctor test is applied to gasoline, naphtha and illuminating oils, to detect the presence of decomposable sulphur compounds.

While the doctor test does not determine the actual presence or absence of sulphur in these materials, it does show whether or not they contain certain sulphur compounds that are likely to be decomposed in storage and develop a yellowish color and offensive odor.

In gasolines that fail to pass the doctor test there is also a possibility that there is sufficient sulphur present to cause corrosion of metal parts of carburetors.

In making the doctor test two volumes of the sample are shaken vigorously with one volume of doctor solution (a mixture of sodium hydroxide, litharge and water) and to this is added a small quantity of flowers of sulphur, after which the mixture is again shaken. If the sample is discolored or if the sulphur film is so dark that its yellow color is noticeably masked, the test is reported as positive and the sample reported as sour. If the mixture remains unchanged in color and the sulphur film is bright yellow, or only very slightly discolored with gray or flecked with black, the test is reported negative and the sample considered sweet.

UNSATURATED HYDROCARBONS

The determination of unsaturated hydrocarbons in gasolines can be made, when required, by mixing a sample with a definite amount of sulphuric acid, shaking it thoroughly, allowing the mixture to stand then separating the two layers by centrifuging and noting the volume of oil absorbed by the acid.

CORROSION

The presence of free sulphur or corrosive sulphur compound in petroleum products, in many cases makes them unsuitable for use.

In gasoline the presence of such material will attack the metallic parts of the carburetor and other feeding mechanisms.

In lubricating oils and greases it will attack the metal surfaces with which they come in contact, and in fuel oil will corrode the burner parts.

A.S.T.M. Tentative Standard D-130-22T is used for this determination, and in general consists of placing a strip of highly-polished pure sheet-copper in the sample to be tested. This is held to a standard temperature for a definite period of time and the presence and action of the sulphur judged by the general condition of the copper strip.

Another method employed is to take a sample of the oil and evaporate it to dryness on a steam bath in a polished copper dish. The condition of the inside of the dish will indicate the possible presence of sulphur and if the gasoline contains undesirable gum-forming constituents a weighable amount of residue will also be left.

FLASH AND FIRE

The flash point of a petroleum product is the temperature at which sufficient vapor is given off to ignite momentarily when exposed to a flame or spark. The fire-point is the temperature at which the oil gives off sufficient vapor to ignite and continue to burn when exposed to a flame or spark. Both tests are made with the same apparatus, the heating being carried on after the flash point has been reached when a determination of the fire-point is required. With the exception of fuel oil all petroleum products with a flash point below 175° F. are determined by A.S.T.M. Standard D-56-21.

The flash point of gasoline is rarely taken, but on illuminating oils and petroleum paint thinners it is a very important specification. If oils of this character have too low a flash point the fire hazard in handling them is greatly increased.

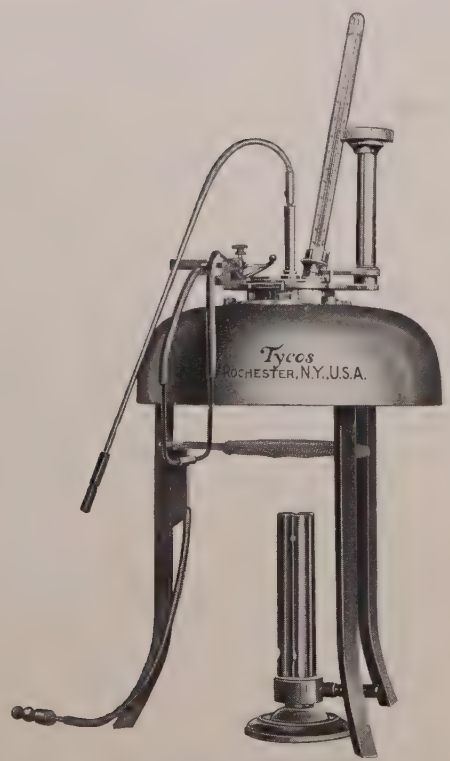


Fig. 154
Pensky-Martens Closed Flash and Fire Test Cup
A.S.T.M. Standard D-93-22

Fig. 155
Cleveland Open Flash and Fire Test Cup
A.S.T.M. Standard D-92-24

In burning oils if the flash point is too high the burning qualities may be impaired, and the commercial value of the product therefore lessened In low flash point determinations, variations in atmospheric pressure have an appreciable effect. It is therefore important to use an accurate barometer when extreme accuracy is desired in this test, correction being determined from table beginning on page 173.

The flash point of fuel oil is determined by the Pensky-Martens Closed Tester (*Fig. 154, page 90*), A.S.T.M. Standard D-93-22.

The flash and fire points of lubricating oils and all other petroleum products with the exception of fuel oil having flash points above 175°F., are determined in the Cleveland Open Cup (*Fig. 155, page 90*), A.S.T.M. Standard D-92-24.

A knowledge of the flash and fire points in lubricating oils is not only a valuable factor in determining the source of the product, but in many cases is one of the most important factors in the use of the material itself.

Under certain conditions it is necessary that lubricants resist exposure to high temperatures without taking fire or giving off vapors that will flash if exposed to a flame or spark.

FLOCK

This test is applied to illuminating oils to determine whether or not they have been thoroughly purified after being treated, so that there will be no substances present that may become insoluble when heated. The presence of such materials tend to reduce the capillarity of the wick and form crusts on the burning edge.

The method of performing this test is to take in a glass flask a definite volume of the oil to be tested, heating it to a specified temperature depending upon the type of oil being tested and examining it to determine its condition after such treatment. The presence of a white flock or sediment indicates incomplete purification.

BURNING, OR LAMP TEST

The burning test as applied to kerosine and other lamp-burning oils indicates the behavior of the oil under actual conditions of use. This test is an indication also as to whether or not the unsaturated bodies have been properly removed from the oil, as, if present these materials are not completely oxidized and produce a smoky flame.

The standard methods are A.S.T.M. Tentative Standard D-187-24-T for burning quality of kerosine oils, A.S.T.M. Tentative Standard D-219-26-T for burning quality of long-time burning oil for railway use, and A.S.T.M. Tentative Standard D-239-26-T for burning quality of mineral colza oil.

In general the test is made by using a standard wick and burner. A definite quantity of the oil to be tested is taken and the wick adjusted to give a certain height of flame. After a given period of time observations are made concerning the clearness of the flame, the condition of the wick to detect any traces of gumming or clogging, and the amount of oil consumed.

In some cases a graduated chimney or other device for measuring the height and width of the flame, is used. In this manner the illuminating value of the oil can be determined also by comparing the dimensions of the flame at the start and end of the test and also the size of the luminous portion of the flame compared with the non-luminous portion for a standard total height.

IODINE ABSORPTION NUMBER

Fixed or fatty oils have an affinity for oxygen and during commercial use they will oxidize and form deposits. Nearly all fixed oils, fats and waxes are mixtures of saturated and unsaturated glycerides, the former not uniting with iodine, while the latter do.

The amount of iodine absorbed by the different kinds of oils, fats and waxes is characteristic. The iodine number is the number of grams of iodine absorbed by the unsaturated constituents present in 100 grams of the oil being tested.

SAPONIFICATION

Pure petroleum oils are not chemically affected by alkalies, but fixed or fatty oils, fats and waxes are saponified when heated with caustic solutions. The saponification number, or value, of a compounded or a fatty oil is the best obtainable index to the percentage of fat or fatty oil in a given product. This value is expressed in the milligrams of potassium hydroxide required to saponify one gram of the material to be tested, A.S.T.M. Tentative Standard D-94-21T.

ACID (ACIDITY)

This test indicates the presence and amount of free organic acids present in petroleum products. It is important that the percentage of acids in most petroleum products, such as lubricating oils, transformer oils and switch oils, as well as gasoline and naphthas, be very low.

The acidity of petroleum oils may be due to the presence of sulphuric or other acids used in the refining processes, or of so-called petroleum acids found in the original crude, or produced during distillation and refining.

Petroleum acids also develop in oils through use, due to the oxidation of the material. Such acids are very weak in their action and do not effect metals with the exception of lead and zinc. The acidity of petroleum products is generally expressed by the number of milligrams of a standard caustic solution, either sodium or potassium hydroxide, required to neutralize the acid present in one gram of the oil being tested. The value may also be expressed in terms of percentage of oleic acid, which is obtained by dividing the value mentioned above by two. Free fatty acids are found also in petroleum oils compounded with fixed oils.

During constant use all oils containing fixed oils oxidize and hydrolize, the result being the formation of free fatty acids and of sticky, gum-like deposits, which may be objectionable. The percentage of fatty oil can be determined by multiplying the saponification number of the compounded oil by 100 and dividing by the saponification number for the fatty oil, where these values for both materials are known.

EMULSIBILITY

This test shows the behavior of lubricating oils when circulated in steam engines, steam turbines or crank cases, where it may come in contact with steam or water. While mineral oils have a low affinity for water it is, however, sufficiently strong in many of them to cause trouble in use. The tendency to emulsify differs considerably with different oils and it therefore becomes necessary to subject such oils to this test to determine their suitability for the use intended.

The steam emulsion test, A.S.T.M. Tentative Standard D-157-23T, is performed by bubbling steam through a definite volume of the oil to be tested, and observing the condition of the oil in a graduated container.

Where oils come in contact with water in use the action can be determined by shaking a sample of the oil with a small quantity of water in a graduated glass container at a temperature approximating that of use. When the mixture is cooled separate layers will be formed, the bottom layer consisting of the clear or slightly clouded water containing no oil, or practically no oil, the middle layer of the emulsified oil and water, and an upper layer of the clear oil containing no water or cloudy oil which may have taken up some moisture. The relation of the volume of these three layers is an indication of the suitability of the oil for the purpose required.

SPECIFIC HEAT

A knowledge of the specific heat of a petroleum product is of value in connection with the design of heating and cooling equipment for its manufacture. As an example it is of value to know the specific heat of oils used in the absorption process to determine the amount of heat and pressure required to carry on the proper distillation.

The specific heat of a lubricating oil is of some importance in connection with its suitability for use. The heat developed by friction in the operation of machinery reduces the viscosity of the lubricating oil. The lower the specific heat of the oil the greater will be the temperature rise in the oil film and therefore a greater reduction in the viscosity.

In cases where abnormal heating takes place an oil with a low specific heat is therefore less suitable than one with a high specific heat.

Specific heat is expressed as the comparison of the amount of heat required to raise one pound of oil 1°F., with that required to raise one pound of water 1°F., the specific heat of water being expressed as 1.000.

FRICTION

The usual physical and chemical tests do not always definitely indicate whether or not an oil will work with entire satisfaction in a certain type of machine. With a view of obtaining actual comparison, between the lubricating qualities of different oils, friction machines of numerous different types have been designed to show the behavior of an oil under the actual conditions of use. Such tests in general are made with a machine consisting of a standard bearing in which a shaft can be driven at a given speed and power. The friction of the bearing can be increased in measured

quantities or the condition of both the bearing and shaft can be adjusted to approximate the actual conditions under which the oil will be required to perform. A sample of the oil is placed in this bearing and the heat generated, and the action of the oil in reducing friction indicates its value as a lubricating medium under such conditions. Friction tests are very complicated and difficult to perform properly and to interpret, and should be undertaken only under competent direction.

MELTING POINT

As paraffin, waxes and petrolatums are defined and graded by the melting point, this is an important test. The temperature at which melted paraffin wax, when allowed to cool under definite prescribed conditions, first shows a minimum rate of temperature change is considered the melting point. This is determined by A.S.T.M. Standard D-87-22.

For petrolatum, the temperature at which the material becomes sufficiently fluid to leave the bulb of the thermometer is considered the melting point.

This test is covered by A.S.T.M. Tentative Standard D-127-24T.

OIL AND MOISTURE

Paraffin wax should contain no appreciable amount of either oil or moisture. The presence and amount of such materials are determined by carefully weighing out a quantity of the wax and placing it in a press between two absorbent mediums, such as linen cloth or blotting paper. It is then subjected for about five minutes to a pressure of one thousand pounds per square inch, the temerature of the material being held constant at 50°F. during the test. The wax is removed and weighed, the loss in weight showing the percentage of oil and moisture present.

NEUTRALIZATION NUMBER

This test indicates the presence of organic materials having acid characteristics, or the contamination of the oils by alkalies and mineral acids. A.S.T.M. Tentative Standard D-188-26T gives the neutralization number as the weight in milligrams of potassium hydroxide required to neutralize one gram of oil. The alkali neutralization number is the weight of acid required to neutralize one gram of oil, expressed in equivalent milligrams of potassium hydroxide. The mineral acid neutralization number is the number of milligrams of potassium hydroxide required to neutralize the mineral acid content in one gram of oil.

HEAT VALUE

This test, A.S.T.M. Tentative Standard D-240-26T, indicates the value of a petroleum product as a heating medium when combustion takes place. It is principally applied to fuel oil and is made in any standard calorimeter, the results being expressed in either calories per gram or B.T.U's per pound.

EVAPORATION

The evaporation test as applied to petroleum products indicates the volatility or the percentage of loss on heating the oil or petroleum product. A.S.T.M. Standard D-6-20 consists in general of heating a sample of the oil at a given rate in a standardized apparatus at definite temperatures for a given time period. The loss in weight of the sample after this treatment is the percent of loss by evaporation.

PRECIPITATION

The Precipitation test is applied to lubricating oils, generally to steam cylinder stock and black oils, to determine the presence of colloidal materials that may be separated out centrifugally. A.S.T.M. Tentative Standard D-91-21T is used, which consists in general of diluting 10 cc of the sample with 90 cc of petroleum naphtha of definite quality, and centrifuging. The number of cubic centimeters of precipitate formed is reported as the precipitation number.

PENETRATION TEST FOR GREASES

As one of the important factors in lubricating greases is the body or hardness of the material it is necessary to determine this property in a definite manner. A.S.T.M. Tentative Standard D-217-26T consists in general of determining the depth of penetration of a standardized cone in the material under a definite load and at a standard temperature. This method is used to measure the original consistency or the worked consistency of number-naught cup grease and all harder greases. The method should be applied only to greases which have not been melted after having been poured and cooled during manufacture.

Thermometers

Fig. 156
Cloud-and-Pour-Test Thermometer A.S.T.M. Tentative Standard D-27-25T

Fig. 157
Low Distillation Thermometer A.S.T.M. Tentative Standard D-86-26T

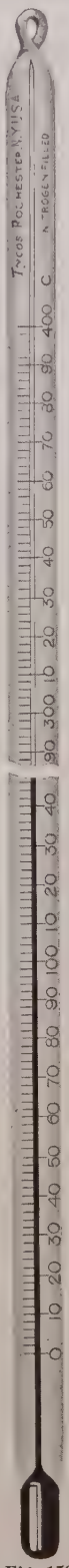


Fig. 158
High Distillation Thermometer A.S.T.M. Tentative Standard D-86-26T

Fig. 159
Flash-and-Fire-Test Thermometer A.S.T.M. Standard D-92-24

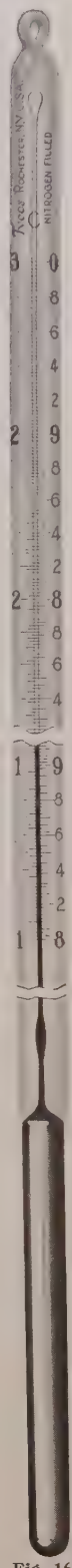


Fig. 160
Calorimeter Thermometer

Thermometers

The importance of the temperature factor and the general consideration of temperature measurements in the various analytical or test methods employed in the petroleum laboratory emphasizes the necessity for standard, accurate and dependable thermometers.

In the majority of these tests the design of the standard apparatus is such that the conditions under which the thermometers are installed are radically different. The fact that the actual outcome of the test is reported entirely on the indication of the thermometer, makes it necessary that this instrument be of as high if not higher degree of accuracy than practically any other portion of the apparatus. Special standardized types of thermometers have been designed and are obtainable for such tests as cloud and pour, distillation, flash and fire, melting point, viscosity, etc.

Unfortunately the features in a thermometer that govern its accuracy and dependability are not visible on the surface of the instrument and cannot be determined except with special apparatus that is very seldom available even in the largest laboratories.

It therefore is important in obtaining thermometers that they be purchased from reliable instrument dealers, and that the name of the manufacturer appear on the goods, the responsibility of the maker being the best guarantee of the instrument.

In many tests there have been no standard thermometer specifications drawn and it is therefore necessary to use a general testing-type instrument. The majority of thermometers manufactured for general testing are standardized for what is known as total immersion, that is the thermometers indicate temperature correctly when they are immersed at a uniform temperature to the top of the mercury column. In the general laboratory use of a thermometer, however, it is impracticable to immerse the instrument sufficiently to obtain this condition and they therefore are used under so-called partial-immersion conditions, that is the bulb and a small portion of the mercury column are in the material the temperature of which is being taken, and a considerable portion of the mercury column extends above the surface of the material and is exposed to conducted and radiated heat and atmospheric temperature. Taking this into consideration and feeling that in the majority of laboratory tests a condition of 3″ immersion could be obtained, the American Society of Testing Materials has standardized on three ranges calibrated for 3″ immersion, which are covered by standard specifications D-182-25, thermometer for general use 0° to 300°F., or corresponding Centigrade, D-183-25 range +20° to 580°F., or corresponding Centigrade, and D-184-25 range +20° to 760°F., or corresponding Centigrade.

All partial-immersion thermometers should be plainly marked to indicate the depth of immersion at which they are calibrated. When no such marking appears on a thermometer it is to be understood that it is standardized at total immersion.

When "partial immersion" thermometers are required and only "total immersion" are available, a so-called stem correction must be applied to the reading to obtain the true temperature.

CORRECTION FOR EMERGENT STEM ON ENGRAVED THERMOMETERS

The so-called "stem correction" for engraved thermometers is very large if the number of degrees emergent and the difference between the temperature of the bath and the space above it is large. It may amount to more than 20°C. (68°F.) for measurements made with an engraved mercury-in-glass thermometer at 400°C. (752°F.) .

For the glass of which practically all thermometers up to 400°C. (752°F:) are made, the stem correction can be very closely computed from the following formula:

Stem Correction = .00016°C. (.000089°F.) X N (T°−t°). N = number of degrees emergent from bath. T = temperature of the bath. t = average temperature of the emergent stem.

The average temperature of the emergent stem "t" may be measured *approximately* by means of a small auxiliary thermometer suspended near the emergent stem, either near the middle or at several points (as for instance at the bottom, middle and top) and the average of these readings taken.

If the thermometer is used in conditions such that it has only a small stem correction, the reading of the thermometer corrected by the actual corrections as shown on a certificate may be taken as the temperature of the bath, since a difference in the temperature of the bath makes a much smaller difference in the value of the stem correction.

Example: The observed temperature is 50°C., at which point the certificate shows there is a correction on the thermometer of +0.5°C., and the thermometer is immersed to the 0°C. mark on the scale, so that 50°C. of the mercury column is projected out into the air and the average temperature of the emergent stem is found to be 20°C., then, Stem Correction = .00016 X 50 (50.5−20) = .244.

Thermometers

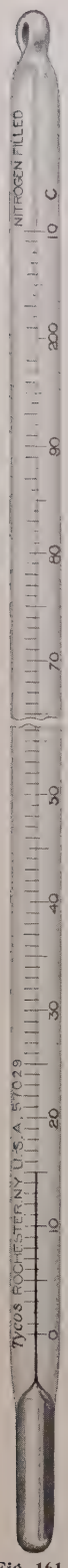


Fig. 161
General Testing Thermometer

Fig. 162
General Testing Thermometer with Armor

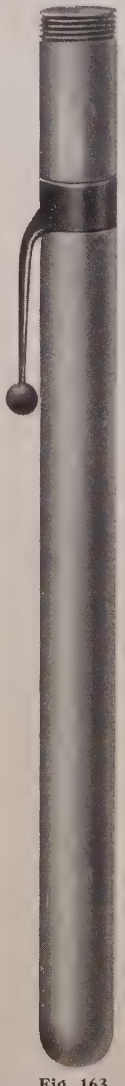
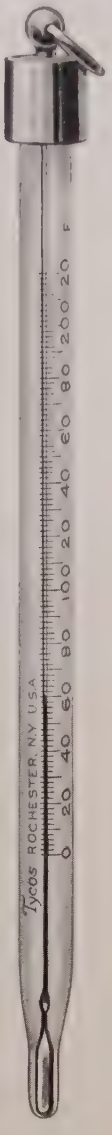


Fig. 163
Pocket Thermometer (Maximum Registering)



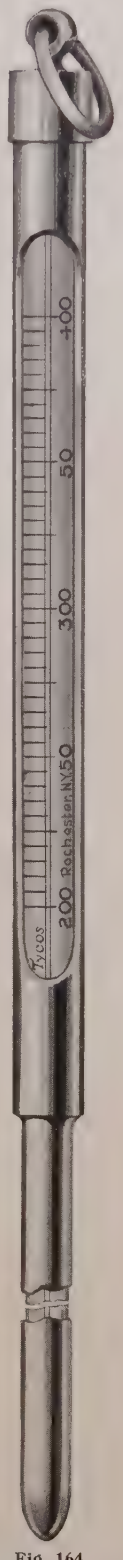
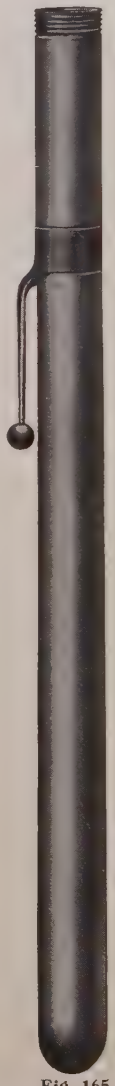


Fig. 164
Asphalt-Testing Thermometer



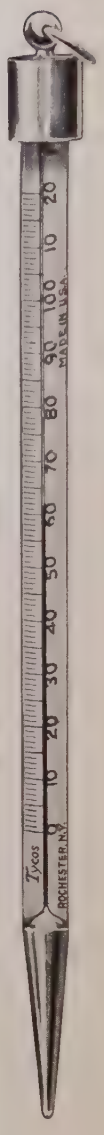


Fig. 165
Pocket Asphalt-Testing Thermometer

As the stem is at a lower temperature than the bulb, the observed reading is too low and this correction must be added to it to find the reading corresponding to the total immersion, i.e., 50°+ .244° = 50.244°. From the certificate there is found to be a further correction of +.5°, making the correct temperature 50.744°C.

If, however, the number of degrees emergent and the difference of temperature between the bath and the space above it are large, it is necessary to determine the stem correction approximately and apply this correction to the corrected reading of the thermometer, in order to get the approximate temperature of the bath. This may be done by using the observed reading corrected from the certificate, as the temperature of the bath, and substituting it in the formula given above. This will determine the approximate stem correction and, by applying this to the observed reading, the approximate temperature of the bath, to a very small degree of error. Then, using this corrected value of the temperature of the bath, the true stem correction can be obtained as closely as required.

Example: The observed temperature is 600°F., at which point the certificate indicates there is no correction and the thermometer is immersed to the 100°F. mark on the scale, so that there is 500°F. of the mercury column projected out into the air and the average temperature of the emergent stem is found to be 200°F., then

The approximate stem correction = .000089 × 500 (600 − 200) = 17.8

The approximate temperature of the bath is therefore 617.8°F. Therefore, a closer approximation to the true stem-correction value will be

Stem Correction = .000089 × 500 (617.8 − 200) = 18.6

As the stem is at a lower temperature than the bulb, the observed reading is too low and this correction must be added to it to find the reading corresponding to total immersion, i.e., 600°+18.6 = 618.6°F.

As there is no correction shown at this point on the certificate the corrected temperature is 618.6°F.

WORKMANSHIP

In the manufacture of the dependable thermometer for laboratory work, every process from the selection of the glass to the final inspection of the finished instrument is performed by expert workmen. The finished glass tube, before being tested and graduated, is subject to special annealing which insures the permanency of the scale indications. In testing and "pointing" these thermometers, the points are taken so close together that the accuracy of the entire scale range is insured. Each instrument finally is inspected and compared with standards and is rejected for any error or for any mechanical defect.

ARMORED THERMOMETERS

Armored Engraved Thermometers are enclosed in a strong nickel-plated steel tube, a portion of which is milled out and the lower end surrounding the bulb perforated, making them easy to read and allowing good circulation at all times around the mercury-filled bulb.

This type of armor offers ample protection to the engraved thermometer and can be removed easily for replacing the glass tube. It is adapted especially for use where temperatures in metal wells are taken with engraved thermometers.

POCKET THERMOMETERS

Pocket Engraved Thermometers are made a convenient length to carry in the pocket, and are furnished in a metal protecting case, provided with a pocket-clip.

MAXIMUM-REGISTERING THERMOMETERS

Maximum-Registering Engraved Thermometers are so constructed that they will give a registration of the maximum temperature to which they are exposed. They are useful particularly for determining temperatures in places where it is impossible or impracticable to read a thermometer while it is being subjected to the existing conditions.

The registering feature consists of a contraction of the bore of the tube, immediately above the bulb, which, while allowing the mercury to rise when heated, prevents the column, on cooling, from receding again into the bulb. The maximum temperature to which the thermometer has been subjected is indicated, therefore, at the top of the mercury column. To get the mercury in the column back into the bulb, grasp the thermometer near the top and subject it to a swinging motion, with the bulb end down. It is impossible of course to shake the mercury column of this type of thermometer below the existing atmospheric temperature or to unite completely the mercury column, and no effort should be made to do this.

Hydrometers

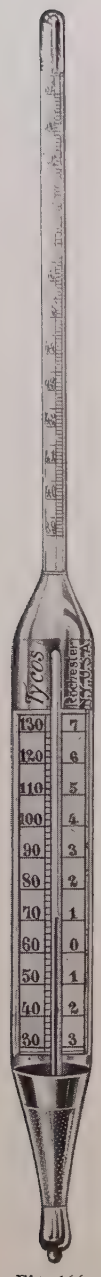


Fig. 166

Thermo-Hydrometer (Thermometer in Float Body) for Transparent Oils

Fig. 167

Thermo-Hydrometer (Thermometer in Stem) for Opaque Oils

Fig. 168

Plain Hydrometer Small Size

Fig. 169

Plain Hydrometer Regular Size

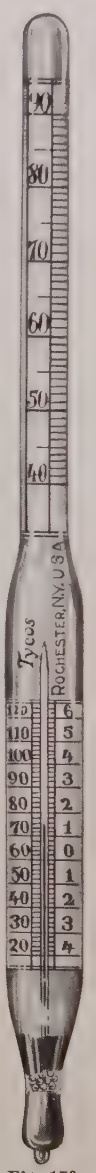


Fig. 170

Thermo-Hydrometer Small Size

Hydrometers

The hydrometer is an instrument employing the general physical law that a floating body displaces its own weight of the liquid in which it floats, and is used to determine the relative densities or weights of liquids.

In the petroleum industry, the hydrometer method for the determination of gravity is applicable to all petroleum products liquid at 60°F.

With the exception of a few special scales, the unit of comparison, or initial point on the hydrometer scale is taken from pure water at a standard temperature. This standard temperature unless otherwise specified is 60°F., meaning that to obtain the true reading it must be taken in a liquid the temperature of which is 60°F. The indication of the hydrometer then shows the exact comparison in weight, or density, between the liquid tested and pure water at 60°F.

The range, i.e. the number of degrees shown on the stem of the hydrometer, should be governed by the degree of accuracy desired in the instrument. When the range is large the subdivisions are not as fine and the action of the hydrometer is more sluggish than where only a few degrees are shown on the stem, the latter allowing both finer and more open subdividing.

HYDROMETER SCALES

The scales principally used on hydrometers for the testing of petroleum products are the Specific Gravity and A.P.I. Scales.

The Specific Gravity Scale is taken with the initial point 1, for distilled water. This is written 1.000 and is divided decimally below 1.000 for liquids lighter than water, and above 1.000 for liquids heavier than water. A liquid the density of which is 50 per cent greater than water will read 1.500 Sp. Gr., and one whose density is 25 per cent lighter than water 0.750.

The A.P.I. Scale was recommended by the U. S. Bureau of Standards, in December 1921, to be used in the petroleum industry, and this scale should be clearly distinguished from and not confused with the original Baumé scale for light liquids.

The relation of the A.P.I. scale to specific gravity is expressed by the formula.

$$\text{Degrees A.P.I.} = \frac{141.5}{\text{sp. gr. } 60°/60°\text{F.}} - 131.5$$

The accuracy of the gravity determination depends principally on the accuracy of the hydrometer. It is, therefore, essential that a reliable and correct type of instrument be used and the accuracy be within the requirements of the U. S. Bureau of Standards for certification, namely instruments graduated in specific gravity to be accurate to one smallest scale division; instruments graduated in A.P.I. scale subdivided in 1° or ½° subdivisions should be accurate to one-half the smallest scale subdivision, when graduated finer than ½° A.P.I. they should be accurate to one smallest scale division.

The spacings of the graduations on a hydrometer scale should not be finer than one-half millimeter apart, or in general coarser than 2 millimeters.

All hydrometers for testing petroleum products should be standardized to show gravity at 60°F., compared to water at 60°F. While in some cases it is much more convenient to use a thermo-hydrometer, that is, the gravity scale and temperature scale combined in one instrument, it is, however, preferable to use two separate instruments, one for determining gravity and one temperature as more accurate determinations can be made. And the latter practice is also more economical from the standpoint of breakage.

The hydrometer tables given in this book apply to all petroleum oils, both crude and refined, produced in the United States. Each grade of oil falls into its proper place in the tables by reason of its gravity.

METHOD OF READING THE HYDROMETER

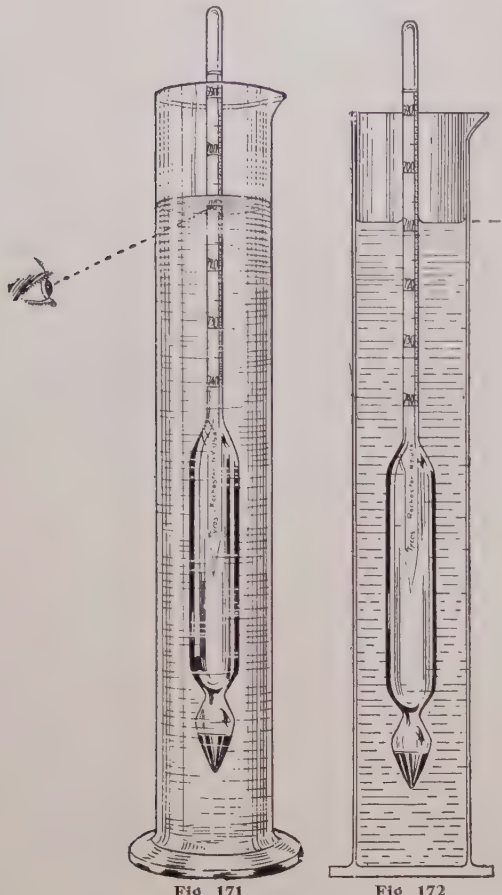


Fig. 171 Fig. 172

The correct method of reading the hydrometer is illustrated in Figs. 171 and 172. The sample of oil is placed in a clean glass jar or cylinder and the hydrometer carefully immersed in it to a point slightly below that to which it naturally sinks and is then allowed to float freely.

The reading should not be taken until the oil and the hydrometer are free from air bubbles and are at rest. In taking the reading the eye should be placed slightly below the plane of the surface of the oil (fig. 171) and then raised slowly until this surface, seen as an ellipse, becomes a straight line (fig. 172). The point at which this line cuts the hydrometer scale should be taken as the reading of the instrument (fig. 172).

In case the oil is not sufficiently clear to allow the reading to be made as above described, it will be necessary to read from above the oil surface and to estimate as accurately as possible the point to which the oil rises on the hydrometer stem. It should be remembered, however, that the instrument is calibrated to give correct readings when read at the principal surface of the liquid. It will be necessary, therefore, to correct the reading at the upper meniscus by an amount equal to the height to which the oil creeps upon the stem of the hydrometer. The amount of this correction may be determined with sufficient accuracy for most purposes by taking a few readings on the upper and the lower meniscus in a clear oil and noting the difference.

A specific-gravity hydrometer will read too low and an A.P.I. hydrometer too high when read at the upper edge of the meniscus. The correction for meniscus height should, therefore, be added to a specific gravity reading and subtracted from an A.P.I. reading. The magnitude of the correction will obviously depend upon the length and value of the subdivisions of the hydrometer scale and must be determined in each case for the particular hydrometer in question.

DETERMINATION OF TEMPERATURE

The determination of the temperature of an oil should be made to a degree of accuracy that is comparable with the accuracy of the determination of the gravity of the oil. If the reading of an A.P.I. hydrometer is made to the nearest 0.1 degree A.P.I., it is necessary that the temperature measurement be made to 1°F. for an oil having an A.P.I. reading of about 58. For an oil having a reading of 90 degrees A.P.I. the temperature measurement must be made to 0.5°F., while for an oil of 10 degrees A.P.I. the temperature measurement may be taken to the nearest 2°F. and have the same order of accuracy as the determination of A.P.I. gravity. It is therefore necessary that the thermometer be free from errors in calibration, so that the temperature as determined may be well within the limits given above.

If the thermometer is not made as a part of the hydrometer, the thermometer should be so placed that the bulb can assume the temperature of the oil, and as much of the mercury column as is feasible should be immersed. This is of considerable importance, especially if the temperature of the oil differs greatly from that of the surrounding air. For example, if the temperature of the oil equals 200°F. an emergent column of 50°F. on the scale (approximately 2 inches) will cause an error in the temperature measurement of about 0.5°F., provided the average temperature of the emergent column equals 90°F.

In reading a thermometer accurately care must be taken that the line of sight is perpendicular to the thermometer scale in order to avoid parallax.

Part 3

(*For Index to Tables, see pages 191 and 192*)

This collection of tables is intended to give those connected with the testing and refining of petroleum products authoritative information.

There have been included not only tables for use in the testing and inspecting of oils, but also those relating to general refinery practice.

The majority of the tables have been copied from circulars of the Bureau of Standards. The others have been obtained from the most authoritative sources possible.

We wish to acknowledge the courtesy of the following in allowing us to copy from their publications, or for other assistance rendered:—Bureau of Standards, American Chemical Society, American Society of Testing Materials, Van Nostrand's Chemical Annual, Smithsonian Institute, Weather Bureau, Vacuum Oil Co., Department of Commerce, L. R. Adkins, Landolt-Bornstein Phys.-Chem. Tabellen, International Critical Tables, and Wheeler Condenser & Engineering Company.

Equivalent Temperature Readings for Fahrenheit and Centigrade Scales

Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.
—459.4	—273.	— 29.20	— 34.	1.	— 17.22
—436.	—260.	— 29.	— 33.89	1.40	— 17.
—418.	—250.	— 28.	— 33.33	2.	— 16.67
—400.	—240.	— 27.40	— 33.	3.	— 16.11
—382.	—230.	— 27.	— 32.78	3.20	— 16.
—364.	—220.	— 26.	— 32.22	4.	— 15.56
—346.	—210.	— 25.60	— 32.	5.	— 15.
—328.	—200.	— 25.	— 31.67	6.	— 14.44
—310.	—190.	— 24.	— 31.11	6.80	— 14.
—292.	—180.	— 23.80	— 31.	7.	— 13.89
—274.	—170.	— 23.	— 30.56	8.	— 13.33
—256.	—160.	— 22.	— 30.	8.60	— 13.
—238.	—150.	— 21.	— 29.44	9.	— 12.78
—220.	—140.	— 20.20	— 29.	10.	— 12.22
—202.	—130.	— 20.	— 28.89	10.40	— 12.
—184.	—120.	— 19.	— 28.33	11.	— 11.67
—166.	—110.	— 18.40	— 28.	12.	— 11.11
—148.	—100.	— 18.	— 27.78	12.20	— 11.
—139.	— 95.	— 17.	— 27.22	13.	— 10.56
—130.	— 90.	— 16.60	— 27.	14.	— 10.
—121.	— 85.	— 16.	— 26.67	15.	— 9.44
—112.	— 80.	— 15.	— 26.11	15.80	— 9.
—103.	— 75.	— 14.80	— 26.	16.	— 8.89
— 94.	— 70.	— 14.	— 25.56	17.	— 8.33
— 85.	— 65.	— 13.	— 25.	17.60	— 8.
— 76.	— 60.	— 12.	— 24.44	18.	— 7.78
— 67.	— 55.	— 11.20	— 24.	19.	— 7.22
— 58.	— 50.	— 11.	— 23.89	19.40	— 7.
— 49.	— 45.	— 10.	— 23.33	20.	— 6.67
— 40.	— 40.	— 9.40	— 23.	21.	— 6.11
— 39.	— 39.44	— 9.	— 22.78	21.20	— 6.
— 38.20	— 39.	— 8.	— 22.22	22.	— 5.56
— 38.	— 38.89	— 7.60	— 22.	23.	— 5.
— 37.	— 38.33	— 7.	— 21.67	24.	— 4.44
— 36.40	— 38.	— 6.	— 21.11	24.80	— 4.
— 36.	— 37.78	— 5.80	— 21.	25.	— 3.89
— 35.	— 37.22	— 5.	— 20.56	26.	— 3.33
— 34.60	— 37.	— 4.	— 20.	26.60	— 3.
— 34.	— 36 67	— 3.	— 19.44	27.	— 2.78
— 33.	— 36.11	— 2.20	— 19.	28.	— 2.22
— 32.80	— 36.	— 2.	— 18.89	28.40	— 2.
— 32.	— 35.56	— 1.	— 18.33	29.	— 1 67
— 31.	— 35.	— 0.40	— 18.	30.	— 1.11
— 30.	— 34.44	0.	— 17.78	30.20	— 1.

Equivalent Temperature Readings for Fahrenheit and Centigrade Scales—Continued

Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.
31.	— 0.56	62.	16.67	92.	33.33
32.	0.	62.60	17.	93.	33.89
33.	0.56	63	17.22	93.20	34.
33.80	1.	64.	17 78	94.	34.44
34.	1.11	64.40	18.	95.	35.
35.	1.67	65.	18.33	96.	35.56
35.60	2.	66.	18.89	96.80	36.
36.	2.22	66.20	19.	97.	36.11
37.	2.78	67	19.44	98.	36.67
37.40	3.	68.	20.	98.60	37.
38.	3.33	69.	20.56	99.	37.22
39.	3.89	69.80	21.	100.	37.78
39.20	4.	70.	21.11	100.40	38.
40.	4.44	71.	21.67	101.	38.33
41.	5.	71.60	22.	102.	38.89
42.	5.56	72.	22.22	102.20	39.
42.80	6.	73.	22.78	103.	39.44
43.	6.11	73.40	23.	104.	40.
44.	6.67	74.	23.33	105.	40.56
44.60	7.	75.	23.89	105.80	41.
45.	7.22	75.20	24.	106.	41.11
46.	7.78	76.	24.44	107.	41.67
46.40	8.	77.	25.	107.60	42.
47.	8.33	78.	25.56	108.	42.22
48.	8.89	78.80	26.	109.	42.78
48.20	9.	79.	26.11	109.40	43.
49.	9.44	80.	26.67	110.	43.33
50.	10.	80.60	27.	111.	43.89
51.	10.56	81.	27.22	111.20	44.
51.80	11.	82.	27.78	112.	44.44
52.	11.11	82.40	28.	113.	45.
53.	11.67	83.	28.33	114.	45.56
53.60	12.	84.	28.89	114.80	46.
54.	12.22	84.20	29.	115.	46.11
55.	12.78	85.	29.44	116.	46.67
55.40	13.	86.	30.	116.60	47.
56.	13.33	87.	30.56	117.	47.22
57.	13.89	87.80	31.	118.	47.78
57.20	14.	88.	31.11	118.40	48.
58.	14.44	89.	31.67	119.	48.33
59.	15.	89.60	32.	120.	48.89
60.	15.56	90.	32.22	120.20	49.
60.80	16.	91.	32.78	121.	49.44
61.	16.11	91.40	33.	122.	50.

Equivalent Temperature Readings for Fahrenheit and Centigrade Scales—Continued

Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.
123.	50.56	**153.**	67.22	183.20	**84.**
123.80	**51.**	**154.**	67.78	**184.**	84.44
124.	51.11	154.40	**68.**	**185.**	**85.**
125.	51.67	**155.**	68.33	**186.**	85.56
125.60	**52.**	**156.**	68.89	186.80	**86.**
126.	52.22	156.20	**69.**	**187.**	86.11
127.	52.78	**157.**	69.44	**188.**	86.67
127.40	**53.**	**158.**	**70.**	188.60	**87.**
128.	53.33	**159.**	70.56	**189.**	87.22
129.	53.89	159.80	**71.**	**190.**	87.78
129.20	**54.**	**160.**	71.11	190.40	**88.**
130.	54.44	**161.**	71.67	**191.**	88.33
131.	**55.**	161.60	**72.**	**192.**	88.89
132.	55.56	**162.**	72.22	192.20	**89.**
132.80	**56.**	**163.**	72.78	**193.**	89.44
133.	56.11	163.40	**73.**	**194.**	**90.**
134.	56.67	**164.**	73.33	**195.**	90.56
134.60	**57.**	**165.**	73.89	195.80	**91.**
135.	57.22	165.20	**74.**	**196.**	91.11
136.	57.78	**166.**	74.44	**197.**	91.67
136.40	**58.**	**167.**	**75.**	197.60	**92.**
137.	58.33	**168.**	75.56	**198.**	92.22
138.	58.89	168.80	**76.**	**199.**	92.78
138.20	**59.**	**169**	76.11	199.40	**93.**
139.	59.44	**170.**	76.67	**200.**	93.33
140	**60.**	170.60	**77.**	**201.**	93.89
141.	60.56	**171.**	77.22	201.20	**94.**
141.80	**61.**	**172.**	77.78	**202.**	94.44
142.	61.11	172.40	**78.**	**203.**	**95.**
143.	61.67	**173.**	78.33	**204.**	95.56
143.60	**62.**	**174.**	78.89	204.80	**96.**
144.	62.22	174.20	**79.**	**205.**	96.11
145.	62.78	**175.**	79.44	**206.**	96.67
145.40	**63.**	**176.**	**80.**	206.60	**97.**
146.	63.33	**177.**	80.56	**207.**	97.22
147.	63.89	177.80	**81.**	**208.**	97.78
147.20	**64.**	**178.**	81.11	208.40	**98.**
148.	64.44	**179.**	81.67	**209.**	98.33
149.	**65.**	179.60	**82.**	**210.**	98.89
150.	65.56	**180.**	82.22	210.20	**99.**
150.80	**66.**	**181.**	82.78	**211.**	99.44
151.	66.11	181.40	**83.**	**212.**	**100.**
152.	66.67	**182.**	83.33	**213.**	100.56
152.60	**67.**	**183.**	83.89	213.80	**101.**

Equivalent Temperature Readings for Fahrenheit and Centigrade Scales—Continued

Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.
214.	101.11	244.40	**118**	**275.**	**135**
215.	101.67	**245**	118.33	**276.**	135.56
215.60	**102.**	**246.**	118.89	276.80	**136**
216	102.22	246.20	**119**	**277**	136.11
217	102.78	**247.**	119 44	**278**	136.67
217.40	**103**	**248**	**120**	278 60	**137.**
218.	103.33	**249**	120 56	**279.**	137.22
219.	103 89	249.80	**121**	**280.**	137 78
219.20	**104.**	**250**	121.11	280.40	**138.**
220.	104.44	**251.**	121 67	**281.**	138.33
221.	**105**	251 60	**122.**	**282.**	138.89
222.	105.56	**252.**	122.22	282 20	**139**
222.80	**106.**	**253**	122.78	**283**	139 44
223	106.11	253.40	**123.**	**284.**	**140**
224.	106.67	**254.**	123.33	**285**	140 56
224.60	**107.**	**255.**	123.89	285.80	**141.**
225.	107.22	255.20	**124.**	**286.**	141.11
226.	107 78	**256.**	124 44	**287**	141.67
226.40	**108.**	**257**	**125**	287.60	**142.**
227.	108.33	**258**	125 56	**288.**	142.22
228.	108.89	258 80	**126**	**289**	142.78
228.20	**109.**	**259**	126.11	289 40	**143**
229	109.44	**260**	126.67	**290**	143.33
230	**110.**	260.60	**127**	**291**	143.89
231.	110 56	**261**	127 22	291.20	**144.**
231.80	**111.**	**262.**	127 78	**292.**	144.44
232.	111.11	262.40	**128**	**293.**	**145**
233.	111.67	**263.**	128.33	**294.**	145.56
233 60	**112**	**264**	128.89	294 80	**146.**
234	112.22	264 20	**129.**	**295**	146.11
235	112.78	**265**	129.44	**296**	146.67
235.40	**113**	**266.**	**130**	296.60	**147.**
236.	113 33	**267**	130.56	**297.**	147.22
237	113.89	267 80	**131.**	**298.**	147.78
237.20	**114.**	**268**	131.11	298.40	**148.**
238.	114 44	**269.**	131.67	**299.**	148.33
239	**115.**	269 60	**132.**	**300.**	148.89
240.	115 56	**270**	132.22	300.20	**149.**
240 80	**116.**	**271**	132.78	**301.**	149.44
241.	116.11	271 40	**133.**	**302.**	**150.**
242.	116.67	**272.**	133.33	**303.**	150.56
242.60	**117.**	**273**	133.89	303.80	**151**
243.	117.22	273.20	**134.**	**304.**	151 11
244	117 78	**274.**	134 44	**305**	151 67

Equivalent Temperature Readings for Fahrenheit and Centigrade Scales—Continued

Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.
305.60	**152**	**336.**	168.89	366.80	**186**
306.	152.22	336.20	**169.**	**367**	186.11
307.	152.78	**337**	169.44	**368**	186 67
307.40	**153.**	**338**	**170.**	368.60	**187**
308.	153.33	**339**	170.56	**369**	187.22
309	153.89	339.80	**171**	**370.**	187.78
309.20	**154.**	**340**	171.11	370 40	**188**
310	154.44	**341**	171 67	**371**	188.33
311	**155**	341 60	**172.**	**372**	188 89
312	155 56	**342**	172 22	372.20	**189**
312.80	**156**	**343**	172 78	**373**	189 44
313	156 11	343 40	**173**	**374**	**190**
314.	156 67	**344**	173 33	**375**	190 56
314.60	**157**	**345**	173.89	375.80	**191**
315.	157 22	345.20	**174**	**376.**	191 11
316	157 78	**346.**	174 44	**377**	191 67
316 40	**158.**	**347**	**175**	377 60	**192.**
317	158.33	**348.**	175.56	**378.**	192.22
318	158.89	348.80	**176.**	**379.**	192.78
318.20	**159.**	**349**	176.11	379 40	**193**
319.	159.44	**350**	176.67	**380**	193 33
320	**160**	350.60	**177**	**381**	193 89
321	160 56	**351.**	177 22	381.20	**194.**
321.80	**161**	**352.**	177 78	**382**	194 44
322	161 11	352.40	**178**	**383**	**195**
323.	161 67	**353**	178.33	**384**	195.56
323.60	**162**	**354.**	178.89	384 80	**196.**
324.	162.22	354.20	**179**	**385**	196.11
325	162.78	**355.**	179 44	**386**	196 67
325 40	**163**	**356**	**180**	386.60	**197**
326.	163 33	**357**	180.56	**387.**	197 22
327	163.89	357 80	**181**	**388**	197 78
327.20	**164**	**358.**	181.11	388.40	**198**
328	164 44	**359.**	181.67	**389**	198.33
329	**165**	359 60	**182.**	**390.**	198 89
330.	165 56	**360.**	182 22	390 20	**199**
330 80	**166**	**361.**	182.78	**391**	199 44
331	166 11	361 40	**183**	**392**	**200.**
332	166 67	**362**	183.33	**393.**	200.56
332.60	**167**	**363.**	183.89	393.80	**201**
333	167 22	363.20	**184.**	**394**	201 11
334.	167 78	**364**	184.44	**395.**	201 67
334.40	**168.**	**365**	**185.**	395.60	**202**
335.	168.33	**366.**	185.56	**396.**	202.22

Equivalent Temperature Readings for Fahrenheit and Centigrade Scales—Continued

Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.
397.	202 78	**427**	219.44	**458.**	236.67
397.40	**203.**	**428**	**220.**	458.60	**237**
398.	203.33	**429**	220 56	**459**	237 22
399.	203.89	429.80	**221**	**460.**	237 78
399.20	**204.**	**430.**	221.11	460.40	**238.**
400.	204 44	**431.**	221 67	**461.**	238 33
401.	**205.**	431.60	**222**	**462.**	238 89
402.	205.56	**432**	222.22	462.20	**239.**
402.80	**206.**	**433**	222.78	**463.**	239.44
403.	206.11	433.40	**223.**	**464.**	**240.**
404.	206.67	**434.**	223.33	**465.**	240.56
404.60	**207**	**435.**	223.89	465.80	**241.**
405.	207.22	435 20	**224.**	**466.**	241.11
406.	207.78	**436**	224.44	**467.**	241.67
406.40	**208.**	**437.**	**225.**	467.60	**242**
407	208.33	**438.**	225.56	**468.**	242.22
408	208.89	438.80	**226.**	**469.**	242.78
408 20	**209.**	**439.**	226.11	469.40	**243.**
409	209.44	**440.**	226 67	**470.**	243.33
410.	**210**	440.60	**227.**	**471.**	243.89
411.	210.56	**441.**	227 22	471.20	**244**
411.80	**211.**	**442.**	227.78	**472.**	244.44
412.	211.11	442.40	**228.**	**473.**	**245.**
413.	211.67	**443.**	228.33	**474.**	245.56
413.60	**212.**	**444**	228.89	474.80	**246.**
414.	212.22	444.20	**229.**	**475.**	246.11
415.	212.78	**445.**	229 44	**476**	246.67
415.40	**213**	**446**	**230.**	476.60	**247**
416.	213.33	**447.**	230.56	**477.**	247.22
417.	213.89	447 80	**231**	**478.**	247 78
417.20	**214.**	**448.**	231 11	478.40	**248.**
418.	214.44	**449.**	231.67	**479.**	248 33
419.	**215.**	449.60	**232.**	**480.**	248.89
420.	215.56	**450.**	232.22	480.20	**249**
420.80	**216.**	**451**	232.78	**481.**	249 44
421.	216.11	451.40	**233**	**482.**	**250.**
422.	216.67	**452**	233.33	**483.**	250 56
422.60	**217.**	**453.**	233 89	483.80	**251.**
423	217.22	453.20	**234.**	**484.**	251.11
424.	217.78	**454.**	234.44	**485**	251 67
424.40	**218.**	**455.**	**235.**	485 60	**252**
425.	218.33	**456.**	235.56	**486.**	252.22
426.	218.89	456.80	**236.**	**487**	252.78
426.20	**219.**	**457.**	236.11	487.40	**253.**

Equivalent Temperature Readings for Fahrenheit and Centigrade Scales—Continued

Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.
488.	253.33	519.	270.56	549.	287.22
489.	253.89	519.80	271.	550.	287.78
489.20	254.	520.	271.11	550.40	288.
490.	254.44	521.	271.67	551.	288.33
491.	255.	521.60	272.	552.	288.89
492.	255.56	522.	272.22	552.20	289.
492.80	256	523.	272.78	553.	289.44
493.	256.11	523.40	273.	554.	290.
494.	256.67	524.	273.33	555.	290.56
494.60	257.	525.	273.89	555.80	291.
495	257.22	525.20	274.	556.	291.11
496.	257.78	526.	274.44	557.	291.67
496.40	258	527.	275.	557.60	292.
497	258.33	528.	275.56	558	292.22
498	258.89	528.80	276.	559.	292.78
498.20	259.	529.	276.11	559.40	293.
499.	259.44	530.	276.67	560.	293.33
500.	260.	530.60	277.	561.	293.89
501.	260.56	531.	277.22	561.20	294.
501.80	261.	532.	277.78	562.	294.44
502.	261 11	532.40	278.	563.	295.
503.	261.67	533.	278 33	564.	295.56
503.60	262.	534.	278.89	564.80	296.
504.	262 22	534.20	279.	565	296.11
505	262 78	535	279.44	566.	296.67
505.40	263	536.	280.	566.60	297.
506	263 33	537.	280.56	567.	297.22
507	263 89	537.80	281	568.	297.78
507 20	264	538.	281.11	568.40	298.
508.	264.44	539	281.67	569.	298.33
509.	265.	539.60	282	570	298.89
510.	265.56	540.	282.22	570.20	299.
510.80	266	541.	282.78	571	299.44
511.	266.11	541.40	283.	572	300.
512.	266.67	542	283.33	573.	300.56
512.60	267	543	283.89	573.80	301.
513.	267.22	543.20	284.	574.	301.11
514.	267.78	544	284 44	575.	301.67
514.40	268.	545	285	575 60	302.
515.	268.33	546	285.56	576.	302.22
516.	268 89	546.80	286	577	302.78
516.20	269	547	286.11	577.40	303.
517.	269.44	548	286.67	578.	303.33
518.	270.	548 60	287	579.	303.89

Equivalent Temperature Readings for Fahrenheit and Centigrade Scales—Continued

Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.
579.20	304.	610	321 11	640.40	338.
580.	304 44	611	321.67	641.	338.33
581.	305.	611.60	322.	642.	338.89
582.	305.56	612.	322.22	642.20	339.
582.80	306.	613.	322.70	643.	339.44
583.	306.11	613.40	323.	644.	340.
584.	306.67	614.	323.33	645.	340.56
584.60	307.	615.	323.89	645.80	341.
585.	307.22	615.20	324.	646.	341.11
586.	307.78	616.	324.44	647.	341.67
586.40	308.	617.	325.	647.60	342.
587.	308.33	618.	325.56	648.	342.22
588.	308.89	618.80	326.	649.	342.78
588.20	309.	619.	326.11	649.40	343.
589.	309.44	620.	326.67	650.	343.33
590.	310.	620.60	327.	651.	343.89
591.	310.56	621.	327.22	651.20	344.
591.80	311.	622.	327.78	652.	344.44
592.	311 11	622.40	328.	653.	345.
593.	311.67	623.	328.33	654.	345.56
593.60	312.	624.	328.89	654.80	346.
594.	312.22	624.20	329	655.	346.11
595.	312.78	625	329.44	656.	346.67
595.40	313.	626.	330.	656.60	347.
596.	313.33	627.	330.56	657.	347.22
597.	313 89	627.80	331.	658.	347.78
597.20	314.	628.	331.11	658.40	348.
598.	314.44	629.	331.67	659.	348.33
599.	315.	629.60	332.	660.	348.89
600	315 56	630.	332.22	660.20	349.
600.80	316.	631.	332.78	661.	349.44
601	316 11	631 40	333.	662.	350.
602.	316.67	632.	333.33	663.	350.56
602.60	317	633.	333.89	663.80	351.
603.	317 22	633.20	334.	664.	351.11
604.	317 78	634.	334.44	665.	351.67
604 40	318	635	335.	665.60	352.
605	318.33	636	335.56	666.	352.22
606.	318 89	636 80	336.	667.	352.78
606.20	319.	637	336.11	667.40	353.
607.	319.44	638.	336.67	668.	353.33
608.	320.	638.60	337.	669.	353.89
609.	320.56	639.	337.22	669.20	354.
609.80	321.	640.	337.78	670.	354.44

Equivalent Temperature Readings for Fahrenheit and Centigrade Scales—Continued

Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.
671	**355.**	701.60	**372.**	**732.**	388.89
672.	355.56	**702.**	372.22	732.20	**389.**
672.80	**356.**	**703.**	372.78	**733.**	389.44
673.	356.11	703.40	**373.**	**734.**	**390.**
674.	356.67	**704.**	373.33	**735.**	390.56
674.60	**357.**	**705.**	373 89	735.80	**391.**
675.	357.22	705.20	**374.**	**736.**	391.11
676.	357.78	**706**	374.44	**737.**	391.67
676 40	**358**	**707.**	**375.**	737.60	**392.**
677.	358.33	**708**	375.56	**738.**	392.22
678.	358 89	708.80	**376**	**739.**	392.78
678.20	**359**	**709.**	376 11	739.40	**393.**
679.	359 44	**710.**	376 67	**740**	393.33
680	**360**	710 60	**377.**	**741.**	393.89
681.	360 56	**711**	377.22	741 20	**394.**
681.80	**361**	**712.**	377.78	**742**	394.44
682	361.11	712.40	**378.**	**743.**	**395.**
683.	361.67	**713.**	378.33	**744.**	395.56
683.60	**362.**	**714.**	378 89	744.80	**396.**
684.	362.22	714 20	**379**	**745.**	396.11
685.	362.78	**715**	379.44	**746.**	396.67
685.40	**363**	**716.**	**380.**	746.60	**397**
686.	363.33	**717.**	380.56	**747**	397.22
687.	363.89	717.80	**381**	**748.**	397.78
687.20	**364.**	**718.**	381.11	748.40	**398.**
688.	364.44	**719.**	381.67	**749.**	398.33
689.	**365**	719.60	**382.**	**750.**	398.89
690.	365.56	**720.**	382.22	750.20	**399.**
690.80	**366.**	**721.**	382.78	**751.**	399.44
691.	366.11	721.40	**383.**	**752.**	**400.**
692.	366.67	**722.**	383.33	**753**	400.56
692.60	**367.**	**723.**	383.89	753.80	**401.**
693.	367.22	723 20	**384.**	**754.**	401.11
694.	367.78	**724.**	384.44	**755.**	401.67
694.40	**368.**	**725.**	**385.**	755.60	**402.**
695.	368.33	**726.**	385.56	**756.**	402.22
696.	368.89	726.80	**386.**	**757.**	402.78
696.20	**369.**	**727.**	386.11	757.40	**403.**
697.	369.44	**728.**	386.67	**758.**	403.33
698.	**370.**	728.60	**387.**	**759.**	403.89
699.	370.56	**729**	387.22	759.20	**404.**
699.80	**371.**	**730**	387.78	**760.**	404.44
700.	371.11	730.40	**388.**	**761.**	**405.**
701.	371.67	**731.**	388.33	**762.**	405 56

Equivalent Temperature Readings for Fahrenheit and Centigrade Scales—Continued

Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.
762.80	**406.**	**793.**	**422.78**	**823**	439.44
763.	406.11	793 40	**423.**	**824.**	**440.**
764.	406 67	**794.**	423.33	**825.**	440.56
764.60	**407.**	**795.**	423.89	825.80	**441.**
765.	407:22	795 20	**424.**	**826.**	441.11
766.	407 78	**796.**	424.44	**827.**	441 67
766.40	**408.**	**797.**	**425.**	827.60	**442.**
767.	408.33	**798.**	425 56	**828.**	442.22
768.	408 89	798.80	**426.**	**829.**	442.78
768.20	**409.**	**799.**	426.11	829.40	**443.**
769.	409.44	**800.**	426.67	**830.**	443.33
770.	**410.**	800.60	**427.**	**831.**	443.89
771.	410.56	**801.**	427.22	831 20	**444.**
771.80	**411.**	**802.**	427 78	**832.**	444.44
772.	411.11	802.40	**428.**	**833.**	**445.**
773.	411.67	**803.**	428.33	**834.**	445.56
773.60	**412.**	**804.**	428.89	834.80	**446.**
774.	412.22	804.20	**429.**	**835.**	446.11
775.	412.78	**805.**	429.44	**836.**	446.67
775.40	**413.**	**806.**	**430.**	836 60	**447**
776.	413.33	**807.**	430.56	**837.**	447 22
777.	413.89	807.80	**431.**	**838.**	447.78
777.20	**414.**	**808.**	431.11	838.40	**448.**
778.	414.44	**809.**	431.67	**839.**	448.33
779.	**415.**	809.60	**432.**	**840.**	448.89
780.	415.56	**810.**	432.22	840.20	**449.**
780.80	**416.**	**811.**	432.78	**841.**	449.44
781.	416.11	811.40	**433.**	**842.**	**450.**
782	416.67	**812.**	433.33	**843.**	450.56
782 60	**417.**	**813.**	433.89	843.80	**451**
783	417 22	813.20	**434.**	**844.**	451.11
784.	417.78	**814.**	434.44	**845.**	451.67
784 40	**418.**	**815**	**435.**	845.60	**452.**
785.	418.33	**816**	435.56	**846.**	452.22
786.	418.89	816.80	**436.**	**847.**	452.78
786.20	**419.**	**817.**	436.11	847.40	**453.**
787.	419.44	**818.**	436.67	**848**	453.33
788.	**420.**	818.60	**437.**	**849.**	453 89
789.	420.56	**819.**	437.22	849.20	**454.**
789.80	**421.**	**820.**	437.78	**850.**	454.44
790	421 11	820.40	**438.**	**851.**	**455.**
791.	421.67	**821.**	438.33	**852.**	455 56
791.60	**422.**	**822.**	438.89	852.80	**456.**
792.	422.22	822.20	**439.**	**853.**	456.11

Equivalent Temperature Readings for Fahrenheit and Centigrade Scales—Continued

Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.
854.	456.67	884.	473.33	915.	490.56
854.60	457	885.	473.89	915.80	491.
855	457.22	885.20	474.	916	491.11
856	457.78	886.	474.44	917	491.67
856.40	458.	887.	475	917.60	492.
857	458.33	888	475.56	918.	492.22
858.	458.89	888.80	476.	919.	492.78
858.20	459	889.	476.11	919.40	493.
859	459.44	890.	476.67	920	493.33
860	460	890.60	477	921.	493.89
861	460.56	891.	477.22	921.20	494.
861 80	461	892.	477 78	922.	494.44
862.	461.11	892.40	478.	923.	495.
863.	461 67	893	478.33	924.	495.56
863 60	462.	894.	478.89	924.80	496.
864.	462.22	894.20	479.	925.	496.11
865	462.78	895.	479.44	926	496.67
865 40	463.	896	480.	926.60	497.
866.	463.33	897	480.56	927	497.22
867	463.89	897.80	481.	928.	497.78
867 20	464.	898.	481.11	928.40	498.
868	464.44	899.	481.67	929.	498.33
869	465.	899.60	482.	930.	498.89
870	465.56	900.	482.22	930.20	499.
870 80	466.	901.	482.78	931.	499.44
871	466.11	901.40	483.	932.	500.
872	466 67	902	483.33	933.	500.56
872 60	467	903.	483.89	933.80	501
873	467 22	903.20	484.	934	501.11
874	467.78	904	484.44	935.	501.67
874 40	468	905	485.	935.60	502.
875	468.33	906	485.56	936.	502.22
876	468.89	906.80	486.	937.	502.78
876 20	469	907	486.11	937 40	503.
877	469 44	908.	486.67	938.	503.33
878	470	908.60	487.	939.	503.89
879	470 56	909.	487.22	939.20	504.
879 80	471	910.	487.78	940.	504.44
880	471 11	910.40	488.	941.	505.
881	471 67	911.	488.33	942.	505.56
881.60	472	912.	488.89	942.80	506
882	472.22	912.20	489.	943.	506.11
883	472 78	913.	489.44	944.	506.67
883.40	473.	914.	490.	944.60	507.

Equivalent Temperature Readings for Fahrenheit and Centigrade Scales—Continued

Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.
945.	507 22	1616.	880.	2408.	1320.
946.	507.78	1634.	890	2426.	1330.
946.40	508.	1652.	900.	2444.	1340.
947.	508.33	1670.	910.	2462.	1350.
948.	508.89	1688.	920.	2480.	1360.
948.20	509.	1706.	930.	2498.	1370.
949.	509.44	1724.	940.	2516.	1380.
950.	510	1742.	950	2534.	1390.
968.	520.	1760	960.	2552.	1400.
986.	530	1778.	970.	2570.	1410.
1004.	540	1796.	980.	2588.	1420.
1022	550	1814.	990	2606.	1430.
1040	560.	1832.	1000.	2624.	1440.
1058	570.	1850.	1010	2642	1450.
1076	580.	1868.	1020	2660.	1460.
1094.	590.	1886.	1030	2678.	1470.
1112.	600.	1904.	1040.	2696	1480.
1130.	610.	1922.	1050.	2714.	1490.
1148.	620.	1940.	1060.	2732	1500.
1166.	630.	1958.	1070	2750.	1510.
1184.	640.	1976.	1080	2768.	1520.
1202.	650.	1994	1090	2786.	1530.
1220.	660.	2012.	1100.	2804.	1540.
1238.	670.	2030	1110	2822.	1550
1256	680.	2048	1120.	2840.	1560.
1274.	690.	2066.	1130.	2858.	1570
1292.	700	2084.	1140	2876.	1580
1310	710	2102.	1150.	2894.	1590.
1328.	720	2120	1160.	2912.	1600.
1346.	730.	2138.	1170.	2930	1510
1364.	740	2156	1180.	2948.	1620.
1382.	750.	2174	1190.	2966	1630.
1400.	760.	2192.	1200.	2984.	1640.
1418.	770	2210.	1210.	3002.	1650.
1436.	780	2228.	1220.	3020.	1660.
1454.	790.	2246.	1230	3038.	1670
1472.	800.	2264.	1240.	3056.	1680.
1490.	810.	2282.	1250	3074.	1690.
1508.	820.	2300	1260	3092.	1700
1528.	830	2318	1270.	3110.	1710
1544.	840.	2336	1280	3128.	1720
1562.	850.	2354.	1290	3146.	1730
1580.	860	2372.	1300.	3164.	1740.
1598.	870.	2390.	1310.	3182.	1750.

Degrees A. P. I., with Corresponding Specific Gravity, Pounds per Gallon, and Gallons per Pound*

Degrees A. P. I.	Specific gravity at 60°/60° F.	Pounds per gallon.	Gallons per pound.	Degrees A. P. I.	Specific gravity at 60°/60° F.	Pounds per gallon.	Gallons per pound.
10.0	1.0000	8.328	0.1201	15.0	0.9659	8.044	0.1243
10.1	.9993	8.322	.1202	15.1	.9652	8.038	.1244
10.2	.9986	8.317	.1202	15.2	.9646	8.033	.1245
10.3	.9979	8.311	.1203	15.3	.9639	8.027	.1246
10.4	.9972	8.305	.1204	15.4	.9632	8.021	.1247
10.5	.9965	8.299	.1205	15.5	.9626	8.016	.1248
10.6	.9958	8.293	.1206	15.6	.9619	8.011	.1248
10.7	.9951	8.287	.1207	15.7	.9613	8.006	.1249
10.8	.9944	8.282	.1207	15.8	.9606	8.000	.1250
10.9	.9937	8.276	.1208	15.9	.9600	7.995	.1251
11.0	.9930	8.270	.1209	16.0	.9593	7.989	.1252
11.1	.9923	8.264	.1210	16.1	.9587	7.984	.1253
11.2	.9916	8.258	.1211	16.2	.9580	7.978	.1253
11.3	.9909	8.252	.1212	16.3	.9574	7.973	.1254
11.4	.9902	8.246	.1213	16.4	.9567	7.967	.1255
11.5	.9895	8.241	.1213	16.5	.9561	7.962	.1256
11.6	.9888	8.235	.1214	16.6	.9554	7.956	.1257
11.7	.9881	8.229	.1215	16.7	.9548	7.951	.1258
11.8	.9874	8.223	.1216	16.8	.9541	7.946	.1258
11.9	.9868	8.218	.1217	16.9	.9535	7.940	.1259
12.0	.9861	8.212	.1218	17.0	.9529	7.935	.1260
12.1	.9854	8.206	.1219	17.1	.9522	7.930	.1261
12.2	.9847	8.201	.1219	17.2	.9516	7.925	.1262
12.3	.9840	8.195	.1220	17.3	.9509	7.919	.1263
12.4	.9833	8.189	.1221	17.4	.9503	7.914	.1264
12.5	.9826	8.183	.1222	17.5	.9497	7.909	.1264
12.6	.9820	8.178	.1223	17.6	.9490	7.903	.1265
12.7	.9813	8.172	.1224	17.7	.9484	7.898	.1266
12.8	.9806	8.166	.1225	17.8	.9478	7.893	.1267
12.9	.9799	8.161	.1225	17.9	.9471	7.887	.1268
13.0	.9792	8.155	.1226	18.0	.9465	7.882	.1269
13.1	.9786	8.150	.1227	18.1	.9459	7.877	.1270
13.2	.9779	8.144	.1228	18.2	.9452	7.871	.1270
13.3	.9772	8.138	.1229	18.3	.9446	7.866	.1271
13.4	.9765	8.132	.1230	18.4	.9440	7.861	.1272
13.5	.9759	8.127	.1230	18.5	.9433	7.856	.1273
13.6	.9752	8.122	.1231	18.6	.9427	7.851	.1274
13.7	.9745	8.116	.1232	18.7	.9421	7.846	.1275
13.8	.9738	8.110	.1233	18.8	.9415	7.841	.1275
13.9	.9732	8.105	.1234	18.9	.9408	7.835	.1276
14.0	.9725	8.099	.1235	19.0	.9402	7.830	.1277
14.1	.9718	8.093	.1236	19.1	.9396	7.825	.1278
14.2	.9712	8.088	.1236	19.2	.9390	7.820	.1279
14.3	.9705	8.082	.1237	19.3	.9383	7.814	.1280
14.4	.9698	8.076	.1238	19.4	.9377	7.809	.1281
14.5	.9692	8.071	.1239	19.5	.9371	7.804	.1281
14.6	.9685	8.066	.1240	19.6	.9365	7.799	.1282
14.7	.9679	8.061	.1241	19.7	.9358	7.793	.1283
14.8	.9672	8.055	.1241	19.8	.9352	7.788	.1284
14.9	.9665	8.049	.1242	19.9	.9346	7.783	.1285

*Bureau of Standards Circular No. 154.

Degrees A. P. I., with Corresponding Specific Gravity, Pounds per Gallon, and Gallons per Pound—Continued

Degrees A. P. I.	Specific gravity at 60°/60° F.	Pounds per gallon.	Gallons per pound.	Degrees A. P. I.	Specific gravity at 60°/60° F.	Pounds per gallon.	Gallons per pound.
20.0	0.9340	7.778	0.1286	25.0	0.9042	7.529	0.1328
20.1	.9334	7.773	.1287	25.1	.9036	7.524	.1329
20.2	.9328	7.768	.1287	25.2	.9030	7.519	.1330
20.3	.9321	7.762	.1288	25.3	.9024	7.514	.1331
20.4	.9315	7.757	.1289	25.4	.9018	7.509	.1332
20.5	.9309	7.752	.1290	25.5	.9013	7.505	.1332
20.6	.9303	7.747	.1291	25.6	.9007	7.500	.1333
20.7	.9297	7.742	.1292	25.7	.9001	7.495	.1334
20.8	.9291	7.737	.1292	25.8	.8996	7.491	.1335
20.9	.9285	7.732	.1293	25.9	.8990	7.486	.1336
21.0	.9279	7.727	.1294	26.0	.8984	7.481	.1337
21.1	.9273	7.722	.1295	26.1	.8978	7.476	.1338
21.2	.9267	7.717	.1296	26.2	.8973	7.472	.1338
21.3	.9260	7.711	.1297	26.3	.8967	7.467	.1339
21.4	.9254	7.706	.1298	26.4	.8961	7.462	.1340
21.5	.9248	7.701	.1299	26.5	.8956	7.458	.1341
21.6	.9242	7.696	.1299	26.6	.8950	7.453	.1342
21.7	.9236	7.691	.1300	26.7	.8944	7.448	.1343
21.8	.9230	7.686	.1301	26.8	.8939	7.443	.1344
21.9	.9224	7.681	.1302	26.9	.8933	7.438	.1344
22.0	.9218	7.676	.1303	27.0	.8927	7.434	.1345
22.1	.9212	7.671	.1304	27.1	.8922	7.429	.1346
22.2	.9206	7.666	.1304	27.2	.8916	7.424	.1347
22.3	.9200	7.661	.1305	27.3	.8911	7.420	.1348
22.4	.9194	7.656	.1306	27.4	.8905	7.415	.1349
22.5	.9188	7.651	.1307	27.5	.8899	7.410	.1350
22.6	.9182	7.646	.1308	27.6	.8894	7.406	.1350
22.7	.9176	7.641	.1309	27.7	.8888	7.401	.1351
22.8	.9170	7.636	.1310	27.8	.8883	7.397	.1352
22.9	.9165	7.632	.1310	27.9	.8877	7.392	.1353
23.0	.9159	7.627	.1311	28.0	.8871	7.387	.1354
23.1	.9153	7.622	.1312	28.1	.8866	7.383	.1354
23.2	.9147	7.617	.1313	28.2	.8860	7.378	.1355
23.3	.9141	7.612	.1314	28.3	.8855	7.373	.1356
23.4	.9135	7.607	.1315	28.4	.8849	7.368	.1357
23.5	.9129	7.602	.1315	28.5	.8844	7.364	.1358
23.6	.9123	7.597	.1316	28.6	.8838	7.360	.1359
23.7	.9117	7.592	.1317	28.7	.8833	7.355	.1360
23.8	.9111	7.587	.1318	28.8	.8827	7.351	.1360
23.9	.9106	7.583	.1319	28.9	.8822	7.346	.1361
24.0	.9100	7.578	.1320	29.0	.8816	7.341	.1362
24.1	.9094	7.573	.1320	29.1	.8811	7.337	.1363
24.2	.9088	7.568	.1321	29.2	.8805	7.332	.1364
24.3	.9082	7.563	.1322	29.3	.8800	7.328	.1365
24.4	.9076	7.558	.1323	29.4	.8794	7.323	.1366
24.5	.9071	7.554	.1324	29.5	.8789	7.318	.1366
24.6	.9065	7.549	.1325	29.6	.8783	7.314	.1367
24.7	.9059	7.544	.1326	29.7	.8778	7.309	.1368
24.8	.9053	7.539	.1326	29.8	.8772	7.305	.1369
24.9	.9047	7.534	.1327	29.9	.8767	7.300	.1370

Degrees A. P. I., with Corresponding Specific Gravity, Pounds per Gallon, and Gallons per Pound—Continued

Degrees A. P. I.	Specific gravity at 60°/60° F.	Pounds per gallon.	Gallons per pound.	Degrees A. P. I.	Specific gravity at 60°/60° F.	Pounds per gallon.	Gallons per pound.
30.0	0.8762	7.296	0.1371	35.0	0.8498	7.076	0.1413
30.1	.8756	7.291	.1372	35.1	.8493	7.072	.1414
30.2	.8751	7.287	.1372	35.2	.8488	7.068	.1415
30.3	.8745	7.282	.1373	35.3	.8483	7.063	.1416
30.4	.8740	7.278	.1374	35.4	.8478	7.059	.1417
30.5	.8735	7.273	.1375	35.5	.8473	7.055	.1417
30.6	.8729	7.268	.1376	35.6	.8468	7.051	.1418
30.7	.8724	7.264	.1377	35.7	.8463	7.047	.1419
30.8	.8718	7.259	.1378	35.8	.8458	7.042	.1420
30.9	.8713	7.255	.1378	35.9	.8453	7.038	.1421
31.0	.8708	7.251	.1379	36.0	.8448	7.034	.1422
31.1	.8702	7.246	.1380	36.1	.8443	7.030	.1422
31.2	.8697	7.242	.1381	36.2	.8438	7.026	.1423
31.3	.8692	7.238	.1382	36.3	.8433	7.022	.1424
31.4	.8686	7.233	.1383	36.4	.8428	7.018	.1425
31.5	.8681	7.228	.1384	36.5	.8423	7.013	.1426
31.6	.8676	7.224	.1384	36.6	.8418	7.009	.1427
31.7	.8670	7.219	.1385	36.7	.8413	7.005	.1428
31.8	.8665	7.215	.1386	36.8	.8408	7.001	.1428
31.9	.8660	7.211	.1387	36.9	.8403	6.997	.1429
32.0	.8654	7.206	.1388	37.0	.8398	6.993	.1430
32.1	.8649	7.202	.1389	37.1	.8393	6.989	.1431
32.2	.8644	7.198	.1389	37.2	.8388	6.985	.1432
32.3	.8639	7.193	.1390	37.3	.8383	6.980	.1433
32.4	.8633	7.188	.1391	37.4	.8378	6.976	.1433
32.5	.8628	7.184	.1392	37.5	.8373	6.972	.1434
32.6	.8623	7.180	.1393	37.6	.8368	6.968	.1435
32.7	.8618	7.176	.1394	37.7	.8363	6.964	.1436
32.8	.8612	7.171	.1395	37.8	.8358	6.960	.1437
32.9	.8607	7.167	.1395	37.9	.8353	6.955	.1438
33.0	.8602	7.163	.1396	38.0	.8348	6.951	.1439
33.1	.8597	7.158	.1397	38.1	.8343	6.947	.1439
33.2	.8591	7.153	.1398	38.2	.8338	6.943	.1440
33.3	.8586	7.149	.1399	38.3	.8333	6.939	.1441
33.4	.8581	7.145	.1400	38.4	.8328	6.935	.1442
33.5	.8576	7.141	.1400	38.5	.8324	6.930	.1443
33.6	.8571	7.137	.1401	38.6	.8319	6.926	.1444
33.7	.8565	7.132	.1402	38.7	.8314	6.922	.1445
33.8	.8560	7.128	.1403	38.8	.8309	6.918	.1446
33.9	.8555	7.123	.1404	38.9	.8304	6.914	.1446
34.0	.8550	7.119	.1405	39.0	.8299	6.910	.1447
34.1	.8545	7.115	.1405	39.1	.8294	6.906	.1448
34.2	.8540	7.111	.1406	39.2	.8289	6.902	.1449
34.3	.8534	7.106	.1407	39.3	.8285	6.898	.1450
34.4	.8529	7.102	.1408	39.4	.8280	6.894	.1451
34.5	.8524	7.098	.1409	39.5	.8275	6.890	.1451
34.6	.8519	7.093	.1410	39.6	.8270	6.886	.1452
34.7	.8514	7.089	.1411	39.7	.8265	6.882	.1453
34.8	.8509	7.085	.1411	39.8	.8260	6.878	.1454
34.9	.8504	7.081	.1412	39.9	.8256	6.874	.1455

Degrees A. P. I., with Corresponding Specific Gravity, Pounds per Gallon, and Gallons per Pound—Continued

Degrees A. P. I.	Specific gravity at 60°/60° F.	Pounds per gallon.	Gallons per pound.	Degrees A. P. I.	Specific gravity at 60°/60° F.	Pounds per gallon.	Gallons per pound.
40.0	0.8251	6.870	0.1456	45.0	0.8017	6.675	0.1498
40.1	.8246	6.866	.1456	45.1	.8012	6.671	.1499
40.2	.8241	6.862	.1457	45.2	.8008	6.667	.1500
40.3	.8236	6.858	.1458	45.3	.8003	6.663	.1501
40.4	.8232	6.854	.1459	45.4	.7999	6.660	.1502
40.5	.8227	6.850	.1460	45.5	.7994	6.656	.1502
40.6	.8222	6.846	.1461	45.6	.7990	6.652	.1503
40.7	.8217	6.842	.1462	45.7	.7985	6.648	.1504
40.8	.8212	6.838	.1462	45.8	.7981	6.645	.1505
40.9	.8208	6.834	.1463	45.9	.7976	6.641	.1506
41.0	.8203	6.830	.1464	46.0	.7972	6.637	.1507
41.1	.8198	6.826	.1465	46.1	.7967	6.633	.1508
41.2	.8193	6.822	.1466	46.2	.7963	6.630	.1508
41.3	.8189	6.818	.1467	46.3	.7958	6.626	.1509
41.4	.8184	6.814	.1468	46.4	.7954	6.622	.1510
41.5	.8179	6.810	.1468	46.5	.7949	6.618	.1511
41.6	.8174	6.806	.1469	46.6	.7945	6.615	.1512
41.7	.8170	6.802	.1470	46.7	.7941	6.611	.1513
41.8	.8165	6.798	.1471	46.8	.7936	6.607	.1514
41.9	.8160	6.794	.1472	46.9	.7932	6.604	.1514
42.0	.8155	6.790	.1473	47.0	.7927	6.600	.1515
42.1	.8151	6.786	.1474	47.1	.7923	6.596	.1516
42.2	.8146	6.782	.1474	47.2	.7918	6.592	.1517
42.3	.8142	6.779	.1475	47.3	.7914	6.589	.1518
42.4	.8137	6.775	.1476	47.4	.7909	6.585	.1519
42.5	.8132	6.771	.1477	47.5	.7905	6.582	.1519
42.6	.8128	6.767	.1478	47.6	.7901	6.578	.1520
42.7	.8123	6.763	.1479	47.7	.7896	6.574	.1521
42.8	.8118	6.759	.1480	47.8	.7892	6.571	.1522
42.9	.8114	6.756	.1480	47.9	.7887	6.567	.1523
43.0	.8109	6.752	.1481	48.0	.7883	6.563	.1524
43.1	.8104	6.748	.1482	48.1	.7879	6.560	.1524
43.2	.8100	6.744	.1483	48.2	.7874	6.556	.1525
43.3	.8095	6.740	.1484	48.3	.7870	6.552	.1526
43.4	.8090	6.736	.1485	48.4	.7865	6.548	.1527
43.5	.8086	6.732	.1485	48.5	.7861	6.545	.1528
43.6	.8081	6.728	.1486	48.6	.7857	6.541	.1529
43.7	.8076	6.724	.1487	48.7	.7852	6.537	.1530
43.8	.8072	6.720	.1488	48.8	.7848	6.534	.1530
43.9	.8067	6.716	.1489	48.9	.7844	6.530	.1531
44.0	.8063	6.713	.1490	49.0	.7839	6.526	.1532
44.1	.8058	6.709	.1491	49.1	.7835	6.523	.1533
44.2	.8054	6.705	.1491	49.2	.7831	6.520	.1534
44.3	.8049	6.701	.1492	49.3	.7826	6.516	.1535
44.4	.8044	6.697	.1493	49.4	.7822	6.512	.1536
44.5	.8040	6.694	.1494	49.5	.7818	6.509	.1536
44.6	.8035	6.690	.1495	49.6	.7813	6.505	.1537
44.7	.8031	6.686	.1496	49.7	.7809	6.501	.1538
44.8	.8026	6.682	.1497	49.8	.7805	6.498	.1539
44.9	.8022	6.679	.1497	49.9	.7800	6.494	.1540

Degrees A. P. I., with Corresponding Specific Gravity, Pounds per Gallon, and Gallons per Pound—Continued

Degrees A. P. I.	Specific gravity at 60°/60° F.	Pounds per gallon.	Gallons per pound.	Degrees A. P. I.	Specific gravity at 60°/60° F.	Pounds per gallon.	Gallons per pound.
50.0	0.7796	6.490	0.1541	55.0	0.7587	6.316	0.1583
50.1	.7792	6.487	.1542	55.1	.7583	6.313	.1584
50.2	.7788	6.484	.1542	55.2	.7579	6.310	.1585
50.3	.7783	6.480	.1543	55.3	.7575	6.306	.1586
50.4	.7779	6.476	.1544	55.4	.7571	6.303	.1587
50.5	.7775	6.473	.1545	55.5	.7567	6.300	.1587
50.6	.7770	6.469	.1546	55.6	.7563	6.296	.1588
50.7	.7766	6.466	.1547	55.7	.7559	6.293	.1589
50.8	.7762	6.462	.1548	55.8	.7555	6.290	.1590
50.9	.7758	6.459	.1548	55.9	.7551	6.287	.1591
51.0	.7753	6.455	.1549	56.0	.7547	6.283	.1592
51.1	.7749	6.451	.1550	56.1	.7543	6.280	.1592
51.2	.7745	6.448	.1551	56.2	.7539	6.276	.1593
51.3	.7741	6.445	.1552	56.3	.7535	6.273	.1594
51.4	.7736	6.441	.1553	56.4	.7531	6.270	.1595
51.5	.7732	6.437	.1554	56 5	.7527	6.266	.1596
51.6	.7728	6.434	.1554	56.6	.7523	6.263	.1597
51.7	.7724	6.430	.1555	56.7	.7519	6.259	.1598
51.8	.7720	6.427	.1556	56.8	.7515	6.256	.1598
51.9	.7715	6.423	.1557	56.9	.7511	6.253	.1599
52.0	.7711	6.420	.1558	57.0	.7507	6.249	.1600
52.1	.7707	6.416	.1559	77.1	.7503	6.246	.1601
52.2	.7703	6.413	.1559	57.2	.7499	6.243	.1602
52.3	.7699	6.410	.1560	57.3	.7495	6.240	.1603
52.4	.7694	6.406	.1561	57.4	.7491	6.236	.1604
52.5	.7690	6.402	.1562	57.5	.7487	6.233	.1604
52.6	.7686	6.399	.1563	57.6	.7483	6.229	.1605
52.7	.7682	6.396	.1563	57.7	.7479	6.226	.1606
52.8	.7678	6.392	.1564	57.8	.7475	6.223	.1607
52.9	.7674	6.389	.1565	57.9	.7471	6.219	.1608
53.0	.7669	6.385	.1566	58.0	.7467	6.216	.1609
53.1	.7665	6.381	.1567	58.1	.7463	6.213	.1610
53.2	.7661	6.378	.1568	58.2	.7459	6.209	.1611
53.3	.7657	6.375	.1569	58.3	.7455	6.206	.1611
53.4	.7653	6.371	.1570	58.4	.7451	6.203	.1612
53.5	.7649	6.368	.1570	58.5	.7447	6.199	.1613
53.6	.7645	6.365	.1571	58.6	.7443	6.196	.1614
53.7	.7640	6.361	.1572	58.7	.7440	6.193	.1615
53.8	.7636	6.357	.1573	58.8	.7436	6.190	.1616
53.9	.7632	6.354	.1574	58.9	.7432	6.187	.1616
54.0	.7628	6.350	.1575	59.0	.7428	6.184	.1617
54.1	.7624	6.347	.1576	59.1	.7424	6.180	.1618
54.2	.7620	6.344	.1576	59.2	.7420	6.177	.1619
54.3	.7616	6.340	.1577	59.3	.7416	6.174	.1620
54.4	.7612	6.337	.1578	59.4	.7412	6.170	.1621
54.5	.7608	6.334	.1579	59.5	.7408	6.167	.1622
54.6	.7603	6.330	.1580	59.6	.7405	6.164	.1622
54.7	.7599	6.326	.1581	59.7	.7401	6.161	.1623
54.8	.7595	6.323	.1582	59.8	.7397	6.158	.1624
54.9	.7591	6.320	.1582	59.9	.7393	6.154	.1625

Degrees A. P. I., with Corresponding Specific Gravity, Pounds per Gallon, and Gallons per Pound—Continued

Degrees A. P. I.	Specific gravity at 60°/60° F.	Pounds per gallon.	Gallons per pound.	Degrees A. P. I.	Specific gravity at 60°/60° F.	Pounds per gallon.	Gallons per pound.
60.0	0.7389	6.151	0.1626	65.0	0.7201	5.994	0.1668
60.1	.7385	6.148	.1627	65.1	.7197	5.991	.1669
60.2	.7381	6.144	.1628	65.2	.7194	5.988	.1670
60.3	.7377	6.141	.1628	65.3	.7190	5.985	.1671
60.4	.7374	6.138	.1629	65.4	.7186	5.982	.1672
60.5	.7370	6.135	.1630	65.5	.7183	5.979	.1673
60.6	.7366	6.132	.1631	65.6	.7179	5.976	.1673
60.7	.7362	6.129	.1632	65.7	.7175	5.973	.1674
60.8	.7358	6.125	.1633	65.8	.7172	5.970	.1675
60.9	.7354	6.122	.1633	65.9	.7168	5.967	.1676
61.0	.7351	6.119	.1634	66.0	.7165	5.964	.1677
61.1	.7347	6.116	.1635	66.1	.7161	5.961	.1678
61.2	.7343	6.113	.1636	66.2	.7157	5.958	.1678
61.3	.7339	6.109	.1637	66.3	.7154	5.955	.1679
61.4	.7335	6.106	.1638	66.4	.7150	5.952	.1680
61.5	.7332	6.103	.1639	66.5	.7146	5.949	.1681
61.6	.7328	6.100	.1639	66.6	.7143	5.946	.1682
61.7	.7324	6.097	.1640	66.7	.7139	5.943	.1683
61.8	.7320	6.094	.1641	66.8	.7136	5.940	.1684
61.9	.7316	6.090	.1642	66.9	.7132	5.937	.1684
62.0	.7313	6.087	.1643	67.0	.7128	5.934	.1685
62.1	.7309	6.084	.1644	67.1	.7125	5.931	.1686
62.2	.7305	6.081	.1644	67.2	.7121	5.928	.1687
62.3	.7301	6.078	.1645	67.3	.7118	5.925	.1688
62.4	.7298	6.075	.1646	67.4	.7114	5.922	.1689
62.5	.7294	6.072	.1647	67.5	.7111	5.919	.1689
62.6	.7290	6.068	.1648	67.6	.7107	5.916	.1690
62.7	.7286	6.065	.1649	67.7	.7103	5.913	.1691
62.8	.7283	6.062	.1650	67.8	.7100	5.910	.1692
62.9	.7279	6.059	.1650	67.9	.7096	5.907	.1693
63.0	.7275	6.056	.1651	68.0	.7093	5.904	.1694
63.1	.7271	6.053	.1652	68.1	.7089	5.901	.1695
63.2	.7268	6.050	.1653	68.2	.7086	5.898	.1695
63.3	.7264	6.047	.1654	68.3	.7082	5.895	.1696
63.4	.7260	6.044	.1655	68.4	.7079	5.892	.1697
63.5	.7256	6.040	.1656	68.5	.7075	5.889	.1698
63.6	.7253	6.037	.1656	68.6	.7071	5.886	.1699
63.7	.7249	6.034	.1657	68.7	.7068	5.883	.1700
63.8	.7245	6.031	.1658	68.8	.7064	5.880	.1701
63.9	.7242	6.028	.1659	68.9	.7061	5.877	.1702
64.0	.7238	6.025	.1660	69.0	.7057	5.874	.1702
64.1	.7234	6.022	.1661	69.1	.7054	5.871	.1703
64.2	.7230	6.019	.1661	69.2	.7050	5.868	.1704
64.3	.7227	6.016	.1662	69.3	.7047	5.866	.1705
64.4	.7223	6.013	.1663	69.4	.7043	5.863	.1706
64.5	.7219	6.010	.1664	69.5	.7040	5.860	.1706
64.6	.7216	6.007	.1665	69.6	.7036	5.857	.1707
64.7	.7212	6.004	.1666	69.7	.7033	5.854	.1708
64.8	.7208	6.000	.1667	69.8	.7029	5.851	.1709
64.9	.7205	5.997	.1668	69.9	.7026	5.848	.1710

Degrees A. P. I., with Corresponding Specific Gravity, Pounds per Gallon, and Gallons per Pound—Continued

Degrees A. P. I.	Specific gravity at 60°/60° F.	Pounds per gallon.	Gallons per pound.	Degrees A. P. I.	Specific gravity at 60°/60° F.	Pounds per gallon.	Gallons per pound.
70.0	0.7022	5.845	0.1711	75.0	0.6852	5.703	0 1753
70.1	.7019	5.842	.1712	75.1	.6849	5.701	.1754
70.2	.7015	5.839	.1713	75.2	.6846	5.698	.1755
70.3	.7012	5.836	.1714	75.3	.6842	5.695	.1756
70.4	.7008	5.833	.1714	75.4	.6839	5.693	.1757
70.5	.7005	5.831	.1715	75.5	.6836	5.690	.1757
70.6	.7001	5.828	.1716	75.6	.6832	5.687	.1758
70.7	.6998	5.825	.1717	75.7	.6829	5.685	.1759
70.8	.6995	5.823	.1717	75.8	.6826	5.682	.1760
70.9	.6991	5.820	.1718	75.9	.6823	5.679	.1761
71.0	.6988	5.817	.1719	76.0	.6819	5.676	.1762
71.1	.6984	5.814	.1720	76.1	.6816	5.673	.1763
71.2	.6981	5.811	.1721	76.2	.6813	5.671	.1763
71.3	.6977	5.808	.1722	76.3	.6809	5.668	.1764
71.4	.6974	5.805	.1723	76.4	.6806	5.665	.1765
71.5	.6970	5.802	.1724	76.5	.6803	5.662	.1766
71.6	.6967	5.799	.1724	76.6	.6800	5.660	.1767
71.7	.6964	5.796	.1725	76.7	.6796	5.657	.1768
71.8	.6960	5.793	.1726	76.8	.6793	5.654	.1769
71.9	.6957	5.791	.1727	76.9	.6790	5.652	.1769
72.0	.6953	5.788	.1728	77.0	.6787	5.649	.1770
72.1	.6950	5.785	.1729	77.1	.6783	5.646	.1771
72.2	.6946	5.782	.1730	77.2	.6780	5.643	.1772
72.3	.6943	5.779	.1730	77.3	.6777	5.641	.1773
72.4	.6940	5.776	.1731	77.4	.6774	5.638	.1774
72.5	.6936	5.773	.1732	77.5	.6770	5.635	.1775
72.6	.6933	5.771	.1733	77.6	.6767	5.632	.1776
72.7	.6929	5.768	.1734	77.7	.6764	5.630	.1776
72.8	.6926	5.765	.1735	77.8	.6761	5.627	.1777
72.9	.6923	5.762	.1736	77.9	.6757	5.624	.1778
73.0	.6919	5.759	.1736	78.0	.6754	5.622	.1779
73.1	.6916	5.757	.1737	78.1	.6751	5.619	.1780
73.2	.6913	5.754	.1738	78.2	.6748	5.617	.1780
73.3	.6909	5.751	.1739	78.3	.6745	5.614	.1781
73.4	.6906	5.748	.1740	78.4	.6741	5.611	.1782
73.5	.6902	5.745	.1741	78.5	.6738	5.608	.1783
73.6	.6899	5.743	.1741	78.6	.6735	5.606	.1784
73.7	.6896	5.740	.1742	78.7	.6732	5.603	.1785
73.8	.6892	5.737	.1743	78.8	.6728	5.600	.1786
73.9	.6889	5.734	.1744	78.9	.6725	5.598	.1786
74.0	.6886	5.731	.1745	79.0	.6722	5.595	.1787
74.1	.6882	5.728	.1746	79.1	.6719	5.592	.1788
74.2	.6879	5.726	.1746	79.2	.6716	5.590	.1789
74.3	.6876	5.723	.1747	79.3	.6713	5.587	.1790
74.4	.6872	5.720	.1748	79.4	.6709	5.584	.1791
74.5	.6869	5.718	.1749	79.5	.6706	5.582	.1791
74.6	.6866	5.715	.1750	79.6	.6703	5.579	.1792
74.7	.6862	5.712	.1751	79.7	.6700	5.577	.1793
74.8	.6859	5.709	.1752	79.8	.6697	5.574	.1794
74.9	.6856	5.706	.1753	79.9	.6693	5.571	.1795

Degrees A. P. I., with Corresponding Specific Gravity, Pounds per Gallon, and Gallons per Pound—Continued

Degrees A. P. I.	Specific gravity at 60°/60° F.	Pounds per gallon.	Gallons per pound.	Degrees A. P. I.	Specific gravity at 60°/60° F.	Pounds per gallon.	Gallons per pound.
80.0	0.6690	5.568	0.1796	85.0	0.6536	5.440	0.1838
80.1	.6687	5.566	.1797	85.1	.6533	5.437	.1839
80.2	.6684	5.563	.1798	85.2	.6530	5.435	.1840
80.3	.6681	5 561	.1798	85.3	.6527	5.432	.1841
80.4	.6678	5 558	.1799	85.4	.6524	5.430	.1842
80.5	.6675	5.556	.1800	85.5	.6521	5.427	.1843
80.6	.6671	5.553	.1801	85.6	.6518	5.425	.1843
80.7	.6668	5.550	.1802	85.7	.6515	5.422	.1844
80.8	.6665	5.548	.1802	85.8	.6512	5.420	.1845
80.9	.6662	5.545	.1803	85.9	.6509	5.417	.1846
81.0	.6659	5.542	.1804	86.0	.6506	5.415	.1847
81.1	.6656	5.540	.1805	86.1	.6503	5.412	.1848
81.2	.6653	5.537	.1806	86.2	.6500	5.410	.1848
81.3	.6649	5.534	.1807	86.3	.6497	5.407	.1849
81.4	.6646	5.532	.1808	86.4	.6494	5.405	.1850
81.5	.6643	5.529	.1809	86.5	.6491	5.402	.1851
81.6	.6640	5.526	.1810	86.6	.6488	5.400	.1852
81.7	.6637	5.524	.1810	86.7	.6485	5.397	.1853
81.8	.6634	5.522	.1811	86.8	.6482	5.395	.1854
81.9	.6631	5.519	.1812	86.9	.6479	5.392	.1855
82.0	.6628	5.516	.1813	87.0	.6476	5.390	.1855
82.1	.6625	5.514	.1814	87.1	.6473	5.387	.1856
82.2	.6621	5.511	.1815	87.2	.6470	5.385	.1857
82.3	.6618	5.508	.1816	87.3	.6467	5.382	.1858
82.4	.6615	5.506	.1816	87.4	.6464	5.380	.1859
82.5	.6612	5.503	.1817	87.5	.6461	5.377	.1860
82.6	.6609	5.501	.1818	87.6	.6458	5.375	.1861
82.7	.6606	5.498	.1819	87.7	.6455	5.372	.1862
82.8	.6603	5.496	.1820	87.8	.6452	5.370	.1862
82.9	.6600	5.493	.1820	87.9	.6449	5.367	.1863
83.0	.6597	5.491	.1821	88.0	.6446	5.365	.1864
83.1	.6594	5.489	.1822	88.1	.6444	5.363	.1865
83.2	.6591	5.486	.1823	88.2	.6441	5.361	.1865
83.3	.6588	5.483	.1824	88.3	.6438	5.358	.1866
83.4	.6584	5.480	.1825	88.4	.6435	5.356	.1867
83.5	.6581	5.477	.1826	88.5	.6432	5.353	.1868
83.6	.6578	5.475	.1826	88.6	.6429	5.351	.1869
83.7	.6575	5.472	.1827	88.7	.6426	5.348	.1870
83.8	.6572	5.470	.1828	88.8	.6423	5.346	.1871
83.9	.6569	5.467	.1829	88.9	.6420	5.343	.1872
84.0	.6566	5.465	.1830	89.0	.6417	5.341	.1872
84.1	.6563	5.462	.1831	89.1	.6414	5.338	.1873
84.2	.6560	5.460	.1832	89.2	.6411	5.336	.1874
84.3	.6557	5.458	.1832	89.3	.6409	5.334	.1875
84.4	.6554	5.455	.1833	89.4	.6406	5.331	.1876
84.5	.6551	5.453	.1834	89.5	.6403	5.329	.1877
84.6	.6548	5.450	.1835	89.6	.6400	5.326	.1878
84.7	.6545	5.448	.1836	89.7	.6397	5.324	.1878
84.8	.6542	5.445	.1837	89.8	.6394	5.321	.1879
84.9	.6539	5.443	.1837	89.9	.6391	5.319	.1880

Degrees A. P. I., with Corresponding Specific Gravity, Pounds per Gallon, and Gallons per Pound—Continued

Degrees A. P. I.	Specific gravity at 60°/60° F.	Pounds per gallon.	Gallons per pound.	Degrees A. P. I.	Specific gravity at 60°/60° F.	Pounds per gallon.	Gallons per pound.
90.0	0.6388	5.316	0.1881	95.0	0.6247	5.199	0.1924
90.1	.6385	5.314	.1882	95.1	.6244	5.196	.1925
90.2	.6382	5.312	.1883	95.2	.6242	5.194	.1925
90.3	.6380	5.310	.1883	95.3	.6239	5.192	.1926
90.4	.6377	5.307	.1884	95.4	.6236	5.190	.1927
90.5	.6374	5.305	.1885	95.5	.6233	5.187	.1928
90.6	.6371	5.302	.1886	95.6	.6231	5.185	.1929
90.7	.6368	5.300	.1887	95.7	.6228	5.183	.1929
90.8	.6365	5.297	.1888	95.8	.6225	5.180	.1930
90.9	.6362	5.295	.1889	95.9	.6223	5.179	.1931
91.0	.6360	5.293	.1889	96.0	.6220	5.176	.1932
91.1	.6357	5.291	.1890	96.1	.6217	5.174	.1933
91.2	.6354	5.288	.1891	96.2	.6214	5.172	.1933
91.3	.6351	5.286	.1892	96.3	.6212	5.170	.1934
91.4	.6348	5.283	.1893	96.4	.6209	5.167	.1935
91.5	.6345	5.281	.1894	96.5	.6206	5.164	.1936
91.6	.6342	5.278	.1895	96.6	.6203	5.162	.1937
91.7	.6340	5.276	.1895	96.7	.6201	5.160	.1938
91.8	.6337	5.274	.1896	96.8	.6198	5.158	.1939
91.9	.6334	5.271	.1897	96.9	.6195	5.156	.1939
92.0	.6331	5.269	.1898	97.0	.6193	5.154	.1940
92.1	.6328	5.266	.1899	97.1	.6190	5.151	.1941
92.2	.6325	5.264	.1900	97.2	.6187	5.149	.1942
92.3	.6323	5.262	.1900	97.3	.6184	5.146	.1943
92.4	.6320	5.260	.1901	97.4	.6182	5.144	.1944
92.5	.6317	5.257	.1902	97.5	.6179	5.142	.1945
92.6	.6314	5.254	.1903	97.6	.6176	5.140	.1946
92.7	.6311	5.252	.1904	97.7	.6174	5.138	.1946
92.8	.6309	5.250	.1905	97.8	.6171	5.136	.1947
92.9	.6306	5.248	.1905	97.9	.6168	5.133	.1948
93.0	.6303	5.246	.1906	98.0	.6166	5.131	.1949
93.1	.6300	5.243	.1907	98.1	.6163	5.129	.1950
93.2	.6297	5.240	.1908	98.2	.6160	5.126	.1951
93.3	.6294	5.238	.1909	98.3	.6158	5.124	.1952
93.4	.6292	5.236	.1910	98.4	.6155	5.122	.1952
93.5	.6289	5.234	.1911	98.5	.6152	5.120	.1953
93.6	.6286	5.232	.1911	98.6	.6150	5.118	.1954
93.7	.6283	5.229	.1912	98.7	.6147	5.116	.1955
93.8	.6281	5.227	.1913	98.8	.6144	5.113	.1956
93.9	.6278	5.225	.1914	98.9	.6141	5.111	.1957
94.0	.6275	5.222	.1915	99.0	.6139	5.109	.1957
94.1	.6272	5.220	.1916	99.1	.6136	5.107	.1958
94.2	.6269	5.217	.1917	99.2	.6134	5.105	.1959
94.3	.6267	5.215	.1918	99.3	.6131	5.102	.1960
94.4	.6264	5.213	.1918	99.4	.6128	5.100	.1961
94.5	.6261	5.210	.1919	99.5	.6126	5.098	.1962
94.6	.6258	5.208	.1920	99.6	.6123	5.096	.1962
94.7	.6256	5.206	.1921	99.7	.6120	5.093	.1963
94.8	.6253	5.204	.1922	99.8	.6118	5.091	.1964
94.9	.6250	5.201	.1923	99.9	.6115	5.089	.1965
				100.0	.6112	5.086	.1966

Specific Gravity, with Corresponding Degrees A. P. I., Pounds per Gallon and Gallons per Pound*

Specific gravity at 60°/60° F.	Degrees A. P. I.	Pounds per gallon.	Gallons per pound.	Specific gravity at 60°/60° F.	Degrees A. P. I.	Pounds per gallon.	Gallons per pound.
0.600	104.33	4.993	0.2003	0.650	86.19	5.410	0.1848
.601	103.94	5.001	.1999	.651	85.86	5.418	.1846
.602	103.55	5.010	.1996	.652	85.52	5.426	.1843
.603	103.16	5.018	.1993	.653	85.19	5.435	.1840
.604	102.77	5.026	.1990	.654	84.86	5.443	.1837
.605	102.38	5.035	.1986	.655	84.53	5.452	.1834
.606	102.00	5.043	.1983	.656	84.20	5.460	.1832
.607	101.61	5.051	.1980	.657	83.87	5.468	.1829
.608	101.23	5.060	.1976	.658	83.55	5.476	.1826
.609	100.85	5.068	.1973	.659	83.22	5.485	.1823
.610	100.47	5.076	.1970	.660	82.89	5.493	.1820
.611	100.09	5.084	.1967	.661	82.57	5.502	.1818
.612	99.71	5.093	.1963	.662	82.25	5.510	.1815
.613	99.33	5.101	.1960	.663	81.92	5.518	.1812
.614	98.96	5.110	.1957	.664	81.60	5.526	.1810
.615	98.58	5.118	.1954	.665	81.28	5.535	.1807
.616	98.21	5.126	.1951	.666	80.96	5.543	.1804
.617	97.84	5.135	.1948	.667	80.64	5.552	.1801
.618	97.46	5.143	.1944	.668	80.33	5.560	.1799
.619	97.09	5.151	.1941	.669	80.01	5.568	.1796
.620	96.73	5.160	.1938	.670	79.69	5.577	.1793
.621	96.36	5.168	.1935	.671	79.38	5.585	.1790
.622	95.99	5.176	.1932	.672	79.07	5.593	.1788
.623	95.63	5.185	.1929	.673	78.75	5.602	.1785
.624	95.26	5.193	.1926	.674	78.44	5.610	.1782
.625	94.90	5.201	.1923	.675	78.13	5.618	.1780
.626	94.54	5.210	.1920	.676	77.82	5.627	.1777
.627	94.18	5.218	.1916	.677	77.51	5.635	.1775
.628	93.82	5.226	.1913	.678	77.20	5.643	.1772
.629	93.46	5.235	.1910	.679	76.89	5.652	.1769
.630	93.10	5.243	.1907	.680	76.59	5.660	.1767
.631	92.75	5.251	.1904	.681	76.28	5.668	.1764
.632	92.39	5.260	.1901	.682	75.98	5.677	.1762
.633	92.04	5.268	.1898	.683	75.67	5.685	.1759
.634	91.69	5.276	.1895	.684	75.37	5.693	.1756
.635	91.33	5.285	.1892	.685	75.07	5.702	.1754
.636	90.98	5.293	.1889	.686	74.77	5.710	.1751
.637	90.63	5.301	.1886	.687	74.47	5.718	.1749
.638	90.29	5.310	.1883	.688	74.17	5.727	.1746
.639	89.94	5.318	.1880	.689	73.87	5.735	.1744
.640	89.59	5.326	.1877	.690	73.57	5.743	.1741
.641	89.25	5.335	.1874	.691	73.28	5.752	.1739
.642	88.90	5.343	.1872	.692	72.98	5.760	.1736
.643	88.56	5.351	.1869	.693	72.68	5.768	.1734
.644	88.22	5.360	.1866	.694	72.39	5.777	.1731
.645	87.88	5.368	.1863	.695	72.10	5.785	.1729
.646	87.54	5.376	.1860	.696	71.80	5.793	.1726
.647	87.20	5.385	.1857	.697	71.51	5.802	.1724
.648	86.86	5.393	.1854	.698	71.22	5.810	.1721
.649	86.53	5.402	.1851	699	70.93	5.818	.1719

*Bureau of Standards Circular No. 154.

Specific Gravity, with Corresponding Degrees A. P. I., Pounds per Gallon, and Gallons per Pound—Continued

Specific gravity at 60°/60° F.	Degrees A. P. I.	Pounds per gallon.	Gallons per pound.	Specific gravity at 60°/60° F.	Degrees A. P. I.	Pounds per gallon.	Gallons per pound.
0.700	70.64	5.827	0.1716	0.750	57.17	6.244	0.1602
.701	70.35	5.835	.1714	.751	56.92	6.252	.1600
.702	70.07	5.843	.1711	.752	56.66	6.260	.1597
.703	69.78	5.852	.1709	.753	56.41	6.269	.1595
.704	69.49	5.860	.1706	.754	56.17	6.277	.1593
.705	69.21	5.868	.1704	.755	55.92	6.285	.1591
.706	68.92	5.877	.1702	.756	55.67	6.294	.1589
.707	68.64	5.885	.1699	.757	55.42	6.302	.1587
.708	68.36	5.894	.1697	.758	55.18	6.310	.1585
.709	68.08	5.902	.1694	.759	54.93	6.319	.1583
.710	67.80	5.910	.1692	.760	54.68	6.327	.1580
.711	67.52	5.918	.1690	.761	54.44	6.335	.1578
.712	67.24	5.927	.1687	.762	54.20	6.344	.1576
.713	66.96	5.935	.1685	.763	53.95	6.352	.1574
.714	66.68	5.944	.1682	.764	53.71	6.360	.1572
.715	66.40	5.952	.1680	.765	53.47	6.369	.1570
.716	66.13	5.960	.1678	.766	53.23	6.377	.1568
.717	65.85	5.968	.1676	.767	52.98	6.386	.1566
.718	65.58	5.977	.1673	.768	52.74	6.394	.1564
.719	65.30	5.985	.1671	.769	52.51	6.402	.1562
.720	65.03	5.994	.1668	.770	52.27	6.410	.1560
.721	64.76	6.002	.1666	.771	52.03	6.419	.1558
.722	64.48	6.010	.1664	.772	51.79	6.427	.1556
.723	64.21	6.018	.1662	.773	51.55	6.436	.1554
.724	63.94	6.027	.1659	.774	51.32	6.444	.1552
.725	63.67	6.035	.1657	.775	51.08	6.452	.1550
.726	63.40	6.044	.1655	.776	50.85	6.460	.1548
.727	63.14	6.052	.1652	.777	50.61	6.469	.1546
.728	62.87	6.060	.1650	.778	50.38	6.477	.1544
.729	62.60	6.068	.1648	.779	50.14	6.486	.1542
.730	62.34	6.077	.1646	.780	49.91	6.494	.1540
.731	62.07	6.085	.1643	.781	49.68	6.502	.1538
.732	61.81	6.094	.1641	.782	49.45	6.510	.1536
.733	61.54	6.102	.1639	.783	49.22	6.519	.1534
.734	61.28	6.110	.1637	.784	48.98	6.527	.1532
.735	61.02	6.119	.1634	.785	48.75	6.536	.1530
.736	60.76	6.127	.1632	.786	48.53	6.544	.1528
.737	60.49	6.135	.1630	.787	48.30	6.552	.1526
.738	60.23	6.144	.1628	.788	48.07	6.560	.1524
.739	59.97	6.152	.1626	.789	47.84	6.569	.1522
.740	59.72	6.160	.1623	.790	47.61	6.577	.1520
.741	59.46	6.169	.1621	.791	47.39	6.586	.1518
.742	59.20	6.177	.1619	.792	47.16	6.594	.1517
.743	58.94	6.185	.1617	.793	46.94	6.602	.1515
.744	58.69	6.194	.1615	.794	46.71	6.611	.1513
.745	58.43	6.202	.1612	.795	46.49	6.619	.1511
.746	58.18	6.210	.1610	.796	46.26	6.627	.1509
.747	57.92	6.219	.1608	.797	46.04	6.636	.1507
.748	57.67	6.227	.1606	.798	45.82	6.644	.1505
.749	57.42	6.235	.1604	.799	45.60	6.652	.1503

Specific Gravity, with Corresponding Degrees A. P. I., Pounds per Gallon, and Gallons per Pound—Continued

Specific gravity at 60°/60° F.	Degrees A. P. I.	Pounds per gallon.	Gallons per pound.	Specific gravity at 60°/60° F.	Degrees A. P. I.	Pounds per gallon.	Gallons per pound.
0.800	45.38	6.661	0.1501	0.850	34.97	7.078	0.1413
.801	45.15	6.669	.1500	.851	34.77	7.086	.1411
.802	44.93	6.677	.1498	.852	34.58	7.094	.1410
.803	44.71	6.686	.1496	.853	34.39	7.103	.1408
.804	44.49	6.694	.1494	.854	34.19	7.111	.1406
.805	44.28	6.702	.1492	.855	34.00	7.119	.1405
.806	44.06	6.711	.1490	.856	33.80	7.128	.1403
.807	43.84	6.719	.1488	.857	33.61	7.136	.1401
.808	43.62	6.727	.1486	.858	33.42	7.144	.1400
.809	43.41	6.736	.1485	.859	33.23	7.153	.1398
.810	43.19	6.744	.1483	.860	33.03	7.161	.1396
.811	42.98	6.752	.1481	.861	32.84	7.169	.1395
.812	42.76	6.761	.1479	.862	32.65	7.178	.1393
.813	42.55	6.769	.1477	.863	32.46	7.186	.1392
.814	42.33	6.777	.1476	.864	32.27	7.194	.1390
.815	42.12	6.786	.1474	.865	32.08	7.203	.1388
.816	41.91	6.794	.1472	.866	31.89	7.211	.1387
.817	41.69	6.802	.1470	.867	31.71	7.219	.1385
.818	41.48	6.811	.1468	.868	31.52	7.228	.1384
.819	41.27	6.819	.1466	.869	31.33	7.236	.1382
.820	41.06	6.827	.1465	.870	31.14	7.244	.1380
.821	40.85	6.836	.1463	.871	30.96	7.253	.1379
.822	40.64	6.844	.1461	.872	30.77	7.261	.1377
.823	40.43	6.852	.1459	.873	30.58	7.269	.1376
.824	40.22	6.861	.1458	.874	30.40	7.278	.1374
.825	40.02	6.869	.1456	.875	30.21	7.286	.1372
.826	39.81	6.877	.1454	.876	30.03	7.294	.1371
.827	39.60	6.886	.1452	.877	29.85	7.303	.1369
.828	39.39	6.894	.1450	.878	29.66	7.311	.1368
.829	39.19	6.902	.1449	.879	29.48	7.319	.1366
.830	38.98	6.911	.1447	.880	29.30	7.328	.1365
.831	38.78	6.919	.1445	.881	29.11	7.336	.1363
.832	38.57	6.927	.1444	.882	28.93	7.344	.1362
.833	38.37	6.936	.1442	.883	28.75	7.353	.1360
.834	38.16	6.944	.1440	.884	28.57	7.361	.1358
.835	37.96	6.952	.1438	.885	28.39	7.369	.1357
.836	37.76	6.961	.1437	.886	28.21	7.378	.1355
.837	37.56	6.969	.1435	.887	28.03	7.386	.1354
.838	37.35	6.978	.1433	.888	27.85	7.394	.1352
.839	37.15	6.986	.1432	.889	27.67	7.403	.1351
.840	36.95	6.994	.1430	.890	27.49	7.411	.1349
.841	36.75	7.002	.1428	.891	27.31	7.419	.1348
.842	36.55	7.011	.1426	.892	27.13	7.428	.1346
.843	36.35	7.019	.1425	.893	26.95	7.436	.1345
.844	36.15	7.028	.1423	.894	26.78	7.444	.1343
.845	35.96	7.036	.1421	.895	26.60	7.453	.1342
.846	35.76	7.044	.1420	.896	26.42	7.461	.1340
.847	35.56	7.052	.1418	.897	26.25	7.469	.1339
.848	35.36	7.061	.1416	.898	26.07	7.478	.1337
.849	35.17	7.069	.1415	.899	25.90	7.486	.1336

Specific Gravity, with Corresponding Degrees A. P. I., Pounds per Gallon, and Gallons per Pound—Continued

Specific gravity at 60°/60° F.	Degrees A. P. I.	Pounds per gallon.	Gallons per pound.	Specific gravity at 60°/60° F.	Degrees A. P. I.	Pounds per gallon.	Gallons per pound.
0.900	25.72	7.494	0.1334	0.950	17.45	7.911	0.1264
.901	25.55	7.503	.1333	.951	17.29	7.920	.1263
.902	25.37	7.511	.1331	.952	17.13	7.928	.1261
.903	25.20	7.519	.1330	.953	16.98	7.937	.1260
.904	25.03	7.528	.1328	.954	16.82	7.945	.1259
.905	24.85	7.536	.1327	.955	16.67	7.953	.1257
.906	24.68	7.544	.1326	.956	16.51	7.962	.1256
.907	24.51	7.553	.1324	.957	16.36	7.970	.1255
.908	24.34	7.561	.1323	.958	16.20	7.978	.1253
.909	24.17	7.569	.1321	.959	16.05	7.987	.1252
.910	23.99	7.578	.1320	.960	15.90	7.995	.1251
.911	23.82	7.586	.1318	.961	15.74	8.003	.1250
.912	23.65	7.594	.1317	.962	15.59	8.012	.1248
.913	23.48	7.603	.1315	.963	15.44	8.020	.1247
.914	23.31	7.611	.1314	.964	15.28	8.028	.1246
.915	23.14	7.620	.1312	.965	15.13	8.036	.1244
.916	22.98	7.628	.1311	.966	14.98	8.045	.1243
.917	22.81	7.636	.1310	.967	14.83	8.053	.1242
.918	22.64	7.645	.1308	.968	14.68	8.062	.1240
.919	22.47	7.653	.1307	.969	14.53	8.070	.1239
.920	22.30	7.661	.1305	.970	14.38	8.078	.1238
.921	22.14	7.670	.1304	.971	14.23	8.087	.1237
.922	21.97	7.678	.1302	.972	14.08	8.095	.1235
.923	21.80	7.686	.1301	.973	13.93	8.103	.1234
.924	21.64	7.695	.1300	.974	13.78	8.112	.1233
.925	21.47	7.703	.1298	.975	13.63	8.120	.1232
.926	21.31	7.711	.1297	.976	13.48	8.128	.1230
.927	21.14	7.720	.1295	.977	13.33	8.137	.1229
.928	20.98	7.728	.1294	.978	13.18	8.145	.1228
.929	20.81	7.736	1293	.979	13.04	8.153	.1227
.930	20.65	7.745	.1291	.980	12.89	8.162	.1225
.931	20.49	7.753	.1290	.981	12.74	8.170	.1224
.932	20.32	7.761	.1288	.982	12.59	8.178	.1223
.933	20.16	7.770	.1287	.983	12.45	8.187	.1221
.934	20.00	7.778	.1286	.984	12.30	8.195	.1220
.935	19.84	7.786	.1284	.985	12.15	8.203	.1219
.936	19.68	7.795	.1283	.986	12.01	8.212	.1218
.937	19.51	7.803	.1282	.987	11.86	8.220	.1217
.938	19.35	7.811	.1280	.988	11.72	8.228	.1215
.939	19.19	7.820	.1279	.989	11.57	8.237	.1214
.940	19.03	7.828	.1278	.990	11.43	8.245	.1213
.941	18.87	7.836	.1276	.991	11.29	8.253	.1212
.942	18.71	7.845	.1275	.992	11.14	8.262	.1210
.943	18.55	7.853	.1273	.993	11.00	8.270	.1209
.944	18.39	7.861	.1272	.994	10.85	8.278	.1208
.945	18.24	7.870	.1271	.995	10.71	8.287	.1207
.946	18.08	7.878	.1269	.996	10.57	8.295	.1206
.947	17.92	7.886	.1268	.997	10.43	8.303	.1204
.948	17.76	7.895	.1267	.998	10.28	8.312	.1203
.949	17.60	7.903	.1265	.999	10.14	8.320	.1202
				1.000	10.00	8.328	.1201

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.

This Table shows the degrees A. P. I. at 60°F. of oils having, at the observed temperatures, the degrees A. P. I. indicated. Example: If the observed degrees A. P. I. at 78° F. is 34.0, the degrees A. P. I. at 60° F. will be 32.7. Intermediate values can be interpolated. Example: If the observed degrees A. P. I. at 78°F. is 34.4, the degrees A. P. I. at 60°F. will be 33.1.

The headings "Observed Degrees A. P. I." and "Observed Temperature," refer to the true indications of the hydrometer and the thermometer; that is, the actual readings of the instruments, corrected for instrumental errors. This table is so computed as to take into account the thermal expansion of the glass of which the hydrometer is made.

This table is based on the investigation of American petroleum oils carried out by the Bureau of Standards and published in Technologic Paper No. 77, supplemented by additional investigations of the rate of expansion of oils at temperatures beyond the range originally covered and tables given in Circular No. 154.

The table applies to all petroleum oils, both crude and refined produced in the United States. Each grade of oil falls into its proper place in the table, by reason of its specific gravity. In the case of oils, containing paraffin or other materials that become solid at low temperatures, the expansion shown by the table is somewhat too small at temperatures below the point of solidification. While California oils have a higher rate of expansion than do oils from the Central and Eastern States, the investigation of the Bureau of Standards found that the difference was so small that it was not sufficient to cause an appreciable error in the results given in this table.

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.

Observed temperature in °F.	Observed degrees A. P. I.								
	10	11	12	13	14	15	16	17	18
	Corresponding degrees A. P. I. at 60° F.								
0....	13.1	14.1	15.2	16.2	17.3	18.3	19.4	20.4	21.5
1....	13.0	14.1	15.1	16.2	17.2	18.3	19.3	20.4	21.4
2....	13.0	14.0	15.1	16.1	17.2	18.2	19.3	20.3	21.4
3....	12.9	14.0	15.0	16.1	17.1	18.2	19.2	20.2	21.3
4....	12.9	13.9	15.0	16.0	17.1	18.1	19.1	20.2	21.2
5....	12.8	13.9	14.9	16.0	17.0	18.0	19.1	20.1	21.2
6....	12.8	13.8	14.9	15.9	16.9	18.0	19.0	20.1	21.1
7....	12.7	13.8	14.8	15.9	16.9	17.9	19.0	20.0	21.1
8....	12.7	13.7	14.8	15.8	16.8	17.9	18.9	20.0	21.0
9....	12.6	13.7	14.7	15.8	16.8	17.8	18.9	19.9	20.9
10....	12.6	13.6	14.6	15.7	16.7	17.8	18.8	19.8	20.9
11....	12.5	13.6	14.6	15.6	16.7	17.7	18.8	19.8	20.8
12....	12.5	13.5	14.5	15.6	16.6	17.6	18.7	19.7	20.8
13....	12.4	13.4	14.5	15.5	16.6	17.6	18.6	19.7	20.7
14....	12.4	13.4	14.4	15.5	16.5	17.5	18.6	19.6	20.6
15....	12.3	13.3	14.4	15.4	16.5	17.5	18.5	19.6	20.6
16....	12.2	13.3	14.3	15.4	16.4	17.4	18.5	19.5	20.5
17....	12.2	13.2	14.3	15.3	16.4	17.4	18.4	19.5	20.5
18....	12.1	13.2	14.2	15.2	16.3	17.3	18.4	19.4	20.4
19....	12.1	13.1	14.2	15.2	16.2	17.3	18.3	19.3	20.4
20....	12.0	13.1	14.1	15.1	16.2	17.2	18.2	19.3	20.3
21....	12.0	13.0	14.0	15.1	16.1	17.1	18.2	19.2	20.2
22....	11.9	13.0	14.0	15.0	16.1	17.1	18.1	19.1	20.2
23....	11.9	12.9	13.9	15.0	16.0	17.0	18.1	19.1	20.1
24....	11.8	12.9	13.9	14.9	16.0	17.0	18.0	19.0	20.1
25....	11.8	12.8	13.8	14.9	15.9	16.9	18.0	19.0	20.0
26....	11.7	12.8	13.8	14.8	15.8	16.9	17.9	18.9	19.9
27....	11.7	12.7	13.7	14.8	15.8	16.8	17.8	18.9	19.9
28....	11.6	12.6	13.7	14.7	15.7	16.7	17.8	18.8	19.8
29....	11.6	12.6	13.6	14.6	15.7	16.7	17.7	18.7	19.8
30....	11.5	12.5	13.6	14.6	15.6	16.6	17.7	18.7	19.7
31....	11.5	12.5	13.5	14.5	15.6	16.6	17.6	18.6	19.7
32....	11.4	12.4	13.4	14.5	15.5	16.5	17.6	18.6	19.6
33....	11.4	12.4	13.4	14.4	15.5	16.5	17.5	18.5	19.5
34....	11.3	12.3	13.3	14.4	15.4	16.4	17.4	18.4	19.5
35....	11.3	12.3	13.3	14.3	15.3	16.4	17.4	18.4	19.4
36....	11.2	12.2	13.2	14.3	15.3	16.3	17.3	18.3	19.4
37....	11.2	12.2	13.2	14.2	15.2	16.3	17.3	18.3	19.3
38....	11.1	12.1	13.1	14.2	15.2	16.2	17.2	18.2	19.2
39....	11.1	12.1	13.1	14.1	15.1	16.1	17.2	18.2	19.2
40....	11.0	12.0	13.0	14.0	15.1	16.1	17.1	18.1	19.1
41....	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.1	19.1
42....	10.9	11.9	12.9	13.9	15.0	16.0	17.0	18.0	19.0
43....	10.8	11.9	12.9	13.9	14.9	15.9	16.9	17.9	18.9
44....	10.8	11.8	12.8	13.8	14.9	15.9	16.9	17.9	18.9
45....	10.7	11.8	12.8	13.8	14.8	15.8	16.8	17.8	18.8
46....	10.7	11.7	12.7	13.7	14.8	15.8	16.8	17.8	18.8
47....	10.6	11.7	12.7	13.7	14.7	15.7	16.7	17.7	18.7
48....	10.6	11.6	12.6	13.6	14.6	15.6	16.7	17.7	18.7
49....	10.6	11.6	12.6	13.6	14.6	15.6	16.6	17.6	18.6

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.								
	10	11	12	13	14	15	16	17	18
	Corresponding degrees A. P. I. at 60° F.								
50....	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5
51....	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5
52....	10.4	11.4	12.4	13.4	14.4	15.4	16.4	17.4	18.4
53....	10.4	11.4	12.4	13.4	14.4	15.4	16.4	17.4	18.4
54....	10.3	11.3	12.3	13.3	14.3	15.3	16.3	17.3	18.3
55....	10.3	11.3	12.3	13.3	14.3	15.3	16.3	17.3	18.3
56....	10.2	11.2	12.2	13.2	14.2	15.2	16.2	17.2	18.2
57....	10.1	11.1	12.1	13.1	14.1	15.1	16.2	17.2	18.2
58....	10.1	11.1	12.1	13.1	14.1	15.1	16.1	17.1	18.1
59....	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0
60....	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0
61....	9.9	10.9	11.9	12.9	13.9	14.9	15.9	16.9	17.9
62....	9.9	10.9	11.9	12.9	13.9	14.9	15.9	16.9	17.9
63....	9.9	10.8	11.8	12.8	13.8	14.8	15.8	16.8	17.8
64....	9.8	10.8	11.8	12.8	13.8	14.8	15.8	16.8	17.8
65....	9.8	10.7	11.7	12.7	13.7	14.7	15.7	16.7	17.7
66....	9.7	10.7	11.7	12.7	13.7	14.7	15.7	16.7	17.7
67....	9.7	10.6	11.6	12.6	13.6	14.6	15.6	16.6	17.6
68....	9.6	10.6	11.6	12.6	13.6	14.6	15.6	16.6	17.6
69....	9.6	10.6	11.5	12.5	13.5	14.5	15.5	16.5	17.5
70....	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.4	17.4
71....	9.5	10.5	11.4	12.4	13.4	14.4	15.4	16.4	17.4
72....	9.4	10.4	11.4	12.4	13.4	14.4	15.4	16.3	17.3
73....	9.4	10.4	11.3	12.3	13.3	14.3	15.3	16.3	17.3
74....	9.3	10.3	11.3	12.3	13.3	14.3	15.2	16.2	17.2
75....	9.3	10.2	11.2	12.2	13.2	14.2	15.2	16.2	17.2
76....	9.2	10.2	11.2	12.2	13.2	14.2	15.1	16.1	17.1
77....	9.2	10.1	11.1	12.1	13.1	14.1	15.1	16.1	17.1
78....	9.1	10.1	11.1	12.1	13.1	14.0	15.0	16.0	17.0
79....	9.1	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0
80....	9.0	10.0	11.0	12.0	13.0	13.9	14.9	15.9	16.9
81....	9.0	9.9	10.9	11.9	12.9	13.9	14.9	15.8	16.8
82....	8.9	9.9	10.9	11.9	12.9	13.8	14.8	15.8	16.8
83....	8.9	9.8	10.8	11.8	12.8	13.8	14.8	15.7	16.7
84....	8.8	9.8	10.8	11.8	12.8	13.7	14.7	15.7	16.7
85....	8.8	9.8	10.7	11.7	12.7	13.7	14.7	15.6	16.6
86....	8.7	9.7	10.7	11.7	12.6	13.6	14.6	15.6	16.6
87....	8.7	9.7	10.6	11.6	12.6	13.6	14.6	15.5	16.5
88....	8.6	9.6	10.6	11.6	12.5	13.5	14.5	15.5	16.5
89....	8.6	9.6	10.5	11.5	12.5	13.5	14.5	15.4	16.4
90....	8.5	9.5	10.5	11.5	12.4	13.4	14.4	15.4	16.4
91....	8.5	9.5	10.4	11.4	12.4	13.4	14.4	15.3	16.3
92....	8.4	9.4	10.4	11.4	12.3	13.3	14.3	15.3	16.3
93....	8.4	9.4	10.3	11.3	12.3	13.3	14.3	15.2	16.2
94....	8.3	9.3	10.3	11.3	12.2	13.2	14.2	15.2	16.2
95....	8.3	9.3	10.2	11.2	12.2	13.2	14.2	15.1	16.1
96....	8.2	9.2	10.2	11.2	12.1	13.1	14.1	15.1	16.0
97....	8.2	9.2	10.1	11.1	12.1	13.1	14.0	15.0	16.0
98....	8.1	9.1	10.1	11.1	12.0	13.0	14.0	15.0	15.9
99....	8.1	9.1	10.0	11.0	12.0	13.0	13.9	14.9	15.9

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.								
	10	11	12	13	14	15	16	17	18
	Corresponding degrees A. P. I. at 60° F.								
100....	8.1	9.0	10.0	11.0	11.9	12.9	13.9	14.9	15.8
101....	8.0	9.0	9.9	10.9	11.9	12.9	13.8	14.8	15.8
102....	8.0	8.9	9.9	10.9	11.8	12.8	13.8	14.8	15.7
103....	7.9	8.9	9.9	10.8	11.8	12.8	13.7	14.7	15.7
104....	7.9	8.8	9.8	10.8	11.7	12.7	13.7	14.7	15.6
105....	7.8	8.8	9.8	10.7	11.7	12.7	13.6	14.6	15.6
106....	7.8	8.8	9.7	10.7	11.7	12.6	13.6	14.6	15.5
107....	7.7	8.7	9.7	10.6	11.6	12.6	13.5	14.5	15.5
108....	7.7	8.7	9.6	10.6	11.6	12.5	13.5	14.5	15.4
109....	7.6	8.6	9.6	10.5	11.5	12.5	13.4	14.4	15.4
110....	7.6	8.6	9.5	10.5	11.5	12.4	13.4	14.4	15.3
111....	7.6	8.5	9.5	10.4	11.4	12.4	13.3	14.3	15.3
112....	7.5	8.5	9.4	10.4	11.4	12.3	13.3	14.2	15.2
113....	7.5	8.4	9.4	10.3	11.3	12.3	13.2	14.2	15.1
114....	7.4	8.4	9.3	10.3	11.3	12.2	13.2	14.1	15.1
115....	7.4	8.3	9.3	10.2	11.2	12.2	13.1	14.1	15.0
116....	7.3	8.3	9.2	10.2	11.2	12.1	13.1	14.0	15.0
117....	7.3	8.2	9.2	10.1	11.1	12.1	13.0	14.0	14.9
118....	7.2	8.2	9.1	10.1	11.1	12.0	13.0	13.9	14.9
119....	7.2	8.1	9.1	10.1	11.0	12.0	12.9	13.9	14.8
120....	7.1	8.1	9.0	10.0	11.0	11.9	12.9	13.8	14.8
121....	7.1	8.0	9.0	10.0	10.9	11.9	12.8	13.8	14.7
122....	7.0	8.0	8.9	9.9	10.9	11.8	12.8	13.7	14.7
123....	7.0	7.9	8.9	9.9	10.8	11.8	12.7	13.7	14.6
124....	6.9	7.9	8.9	9.8	10.8	11.7	12.7	13.6	14.6
125....	6.9	7.8	8.8	9.8	10.7	11.7	12.6	13.6	14.5
126....	6.9	7.8	8.8	9.7	10.7	11.6	12.6	13.5	14.5
127....	6.8	7.8	8.7	9.7	10.6	11.6	12.5	13.5	14.4
128....	6.8	7.7	8.7	9.6	10.6	11.5	12.5	13.4	14.4
129....	6.7	7.7	8.6	9.6	10.5	11.5	12.4	13.4	14.3
130....	6.7	7.6	8.6	9.5	10.5	11.4	12.4	13.3	14.3
131....	6.6	7.6	8.5	9.5	10.4	11.4	12.3	13.3	14.2
132....	6.6	7.5	8.5	9.4	10.4	11.3	12.3	13.2	14.2
133....	6.5	7.5	8.4	9.4	10.3	11.3	12.2	13.2	14.1
134....	6.5	7.4	8.4	9.3	10.3	11.2	12.2	13.1	14.1
135....	6.4	7.4	8.3	9.3	10.2	11.2	12.1	13.1	14.0
136....	6.4	7.4	8.3	9.3	10.2	11.1	12.1	13.0	14.0
137....	6.4	7.3	8.2	9.2	10.1	11.1	12.0	13.0	13.9
138....	6.3	7.3	8.2	9.2	10.1	11.0	12.0	12.9	13.9
139....	6.3	7.2	8.2	9.1	10.1	11.0	11.9	12.9	13.8
140....	6.2	7.2	8.1	9.1	10.0	10.9	11.9	12.8	13.8
141....	6.2	7.1	8.1	9.0	10.0	10.9	11.8	12.8	13.7
142....	6.1	7.1	8.0	9.0	9.9	10.8	11.8	12.7	13.7
143....	6.1	7.0	8.0	8.9	9.9	10.8	11.8	12.7	13.6
144....	6.0	7.0	7.9	8.9	9.8	10.7	11.7	12.6	13.6
145....	6.0	6.9	7.9	8.8	9.8	10.7	11.7	12.6	13.5
146....	6.0	6.9	7.8	8.8	9.7	10.6	11.6	12.5	13.5
147....	5.9	6.9	7.8	8.7	9.7	10.6	11.6	12.5	13.4
148....	5.9	6.8	7.7	8.7	9.6	10.6	11.5	12.4	13.4
149....	5.8	6.8	7.7	8.7	9.6	10.5	11.5	12.4	13.3

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.								
	10	11	12	13	14	15	16	17	18
	Corresponding degrees A. P. I. at 60° F.								
150....	5.8	6.7	7.7	8.6	9.5	10.5	11.4	12.3	13.3
151....	5.7	6.7	7.6	8.6	9.5	10.4	11.4	12.3	13.2
152....	5.7	6.6	7.6	8.5	9.4	10.4	11.3	12.2	13.2
153....	5.6	6.6	7.5	8.5	9.4	10.3	11.3	12.2	13.1
154....	5.6	6.5	7.5	8.4	9.4	10.3	11.2	12.1	13.1
155....	5.6	6.5	7.4	8.4	9.3	10.2	11.2	12.1	13.0
156....	5.5	6.4	7.4	8.3	9.3	10.2	11.1	12.0	13.0
157....	5.5	6.4	7.3	8.3	9.2	10.1	11.1	12.0	12.9
158....	5.4	6.4	7.3	8.2	9.2	10.1	11.0	11.9	12.9
159....	5.4	6.3	7.3	8.2	9.1	10.0	11.0	11.9	12.8
160....	5.3	6.3	7.2	8.1	9.1	10.0	10.9	11.8	12.8
161....	5.3	6.2	7.2	8.1	9.0	10.0	10.9	11.8	12.7
162....	5.3	6.2	7.1	8.1	9.0	9.9	10.8	11.7	12.7
163....	5.2	6.2	7.1	8.0	8.9	9.9	10.8	11.7	12.6
164....	5.2	6.1	7.0	8.0	8.9	9.8	10.7	11.7	12.6
165....	5.1	6.1	7.0	7.9	8.8	9.8	10.7	11.6	12.5
166....	5.1	6.0	6.9	7.9	8.8	9.7	10.6	11.6	12.5
167....	5.0	6.0	6.9	7.8	8.7	9.7	10.6	11.5	12.4
168....	5.0	5.9	6.9	7.8	8.7	9.6	10.6	11.5	12.4
169....	5.0	5.9	6.8	7.8	8.7	9.6	10.5	11.4	12.3
170....	4.9	5.9	6.8	7.7	8.6	9.5	10.5	11.4	12.3
171....	4.9	5.8	6.7	7.7	8.6	9.5	10.4	11.3	12.2
172....	4.9	5.8	6.7	7.6	8.5	9.5	10.4	11.3	12.2
173....	4.8	5.7	6.7	7.6	8.5	9.4	10.3	11.2	12.1
174....	4.8	5.7	6.6	7.6	8.5	9.4	10.3	11.2	12.1
175....	4.7	5.6	6.6	7.5	8.4	9.3	10.2	11.2	12.1
176....	4.7	5.6	6.5	7.5	8.4	9.3	10.2	11.1	12.0
177....	4.7	5.6	6.5	7.4	8.3	9.2	10.1	11.1	12.0
178....	4.6	5.5	6.4	7.4	8.3	9.2	10.1	11.0	11.9
179....	4.6	5.5	6.4	7.3	8.2	9.2	10.1	11.0	11.9
180....	4.5	5.4	6.4	7.3	8.2	9.1	10.0	10.9	11.8
181....	4.5	5.4	6.3	7.3	8.2	9.1	10.0	10.9	11.8
182....	4.4	5.4	6.3	7.2	8.1	9.0	9.9	10.8	11.7
183....	4.4	5.3	6.2	7.2	8.1	9.0	9.9	10.8	11.7
184....	4.3	5.3	6.2	7.1	8.0	8.9	9.8	10.7	11.6
185....	4.3	5.2	6.1	7.1	8.0	8.9	9.8	10.7	11.6
186....	4.3	5.2	6.1	7.0	7.9	8.8	9.8	10.6	11.6
187....	4.2	5.1	6.1	7.0	7.9	8.8	9.7	10.6	11.5
188....	4.2	5.1	6.0	6.9	7.8	8.7	9.7	10.6	11.5
189....	4.1	5.0	6.0	6.9	7.8	8.7	9.6	10.5	11.4
190....	4.1	5.0	5.9	6.9	7.8	8.7	9.6	10.5	11.4
191....	4.1	5.0	5.9	6.8	7.7	8.6	9.5	10.4	11.3
192....	4.0	4.9	5.8	6.8	7.7	8.6	9.5	10.4	11.3
193....	4.0	4.9	5.8	6.7	7.6	8.5	9.4	10.3	11.2
194....	3.9	4.9	5.8	6.7	7.6	8.5	9.4	10.3	11.2
195....	3.9	4.8	5.7	6.6	7.5	8.4	9.3	10.2	11.1

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.								
	19	20	21	22	23	24	25	26	27
	Corresponding degrees A. P. I. at 60° F.								
0....	22.5	23.6	24.6	25.7	26.8	27.8	28.9	30.0	31.0
1....	22.5	23.5	24.6	25.6	26.7	27.8	28.8	29.9	31.0
2....	22.4	23.5	24.5	25.6	26.6	27.7	28.7	29.8	30.9
3....	22.3	23.4	24.4	25.5	26.5	27.6	28.7	29.7	30.8
4....	22.3	23.3	24.4	25.4	26.5	27.5	28.6	29.6	30.7
5....	22.2	23.3	24.3	25.4	26.4	27.5	28.5	29.6	30.6
6....	22.2	23.2	24.2	25.3	26.3	27.4	28.5	29.5	30.6
7....	22.1	23.1	24.2	25.2	26.3	27.3	28.4	29.4	30.5
8....	22.1	23.1	24.1	25.2	26.2	27.3	28.3	29.4	30.4
9....	22.0	23.0	24.1	25.1	26.2	27.2	28.3	29.3	30.4
10....	21.9	23.0	24.0	25.0	26.1	27.1	28.2	29.2	30.3
11....	21.9	22.9	23.9	25.0	26.0	27.1	28.1	29.2	30.2
12....	21.8	22.8	23.9	24.9	26.0	27.0	28.1	29.1	30.2
13....	21.7	22.8	23.8	24.9	25.9	26.9	28.0	29.0	30.1
14....	21.7	22.7	23.7	24.8	25.8	26.9	27.9	29.0	30.0
15....	21.6	22.7	23.7	24.7	25.8	26.8	27.9	28.9	30.0
16....	21.6	22.6	23.6	24.7	25.7	26.7	27.8	28.8	29.9
17....	21.5	22.6	23.6	24.6	25.7	26.7	27.7	28.8	29.8
18....	21.5	22.5	23.5	24.6	25.6	26.6	27.7	28.7	29.8
19....	21.4	22.4	23.4	24.5	25.5	26.5	27.6	28.6	29.7
20....	21.3	22.4	23.4	24.4	25.5	26.5	27.5	28.6	29.6
21....	21.3	22.3	23.3	24.4	25.4	26.4	27.5	28.5	29.5
22....	21.2	22.2	23.3	24.3	25.3	26.4	27.4	28.4	29.5
23....	21.2	22.2	23.2	24.3	25.3	26.3	27.3	28.4	29.4
24....	21.1	22.1	23.1	24.2	25.2	26.2	27.3	28.3	29.3
25....	21.0	22.1	23.1	24.1	25.2	26.2	27.2	28.3	29.3
26....	21.0	22.0	23.0	24.1	25.1	26.1	27.1	28.2	29.2
27....	20.9	21.9	23.0	24.0	25.0	26.0	27.1	28.1	29.1
28....	20.8	21.9	22.9	23.9	24.9	26.0	27.0	28.0	29.1
29....	20.8	21.8	22.8	23.8	24.9	25.9	26.9	28.0	29.0
30....	20.7	21.7	22.8	23.8	24.8	25.8	26.9	27.9	28.9
31....	20.7	21.7	22.7	23.7	24.7	25.8	26.8	27.8	28.9
32....	20.6	21.6	22.7	23.7	24.7	25.7	26.8	27.8	28.8
33....	20.6	21.6	22.6	23.6	24.6	25.7	26.7	27.7	28.7
34....	20.5	21.5	22.5	23.6	24.6	25.6	26.6	27.7	28.7
35....	20.4	21.4	22.5	23.5	24.5	25.5	26.6	27.6	28.6
36....	20.4	21.4	22.4	23.4	24.4	25.5	26.5	27.5	28.5
37....	20.3	21.3	22.3	23.4	24.4	25.4	26.4	27.4	28.5
38....	20.3	21.3	22.3	23.3	24.3	25.3	26.3	27.4	28.4
39....	20.2	21.2	22.2	23.3	24.3	25.3	26.3	27.3	28.3
40....	20.1	21.2	22.2	23.2	24.2	25.2	26.2	27.3	28.3
41....	20.1	21.1	22.1	23.1	24.2	25.2	26.2	27.2	28.2
42....	20.0	21.0	22.1	23.1	24.1	25.1	26.1	27.1	28.2
43....	20.0	21.0	22.0	23.0	24.0	25.0	26.0	27.1	28.1
44....	19.9	20.9	21.9	23.0	24.0	25.0	26.0	27.0	28.0
45....	19.9	20.9	21.9	22.9	23.9	24.9	25.9	26.9	28.0
46....	19.8	20.8	21.8	22.8	23.8	24.8	25.9	26.9	27.9
47....	19.7	20.7	21.7	22.8	23.8	24.8	25.8	26.8	27.8
48....	19.7	20.7	21.7	22.7	23.7	24.7	25.7	26.8	27.8
49....	19.6	20.6	21.6	22.7	23.7	24.7	25.7	26.7	27.7

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.								
	19	20	21	22	23	24	25	26	27
	Corresponding degrees A. P. I. at 60° F.								
50....	19.6	20.6	21.6	22.6	23.6	24.6	25.6	26.6	27.6
51....	19.5	20.5	21.5	22.5	23.5	24.5	25.5	26.6	27.6
52....	19.4	20.5	21.5	22.5	23.5	24.5	25.5	26.5	27.5
53....	19.4	20.4	21.4	22.4	23.4	24.4	25.4	26.4	27.4
54....	19.3	20.3	21.3	22.3	23.3	24.4	25.4	26.4	27.4
55....	19.3	20.3	21.3	22.3	23.3	24.3	25.3	26.3	27.3
56....	19.2	20.2	21.2	22.2	23.2	24.2	25.2	26.2	27.3
57....	19.2	20.2	21.2	22.2	23.2	24.2	25.2	26.2	27.2
58....	19.1	20.1	21.1	22.1	23.1	24.1	25.1	26.1	27.1
59....	19.0	20.1	21.1	22.1	23.1	24.1	25.1	26.1	27.1
60....	19.0	20.0	21.0	22.0	23.0	24.0	25.0	26.0	27.0
61....	18.9	19.9	20.9	21.9	22.9	23.9	24.9	25.9	26.9
62....	18.9	19.9	20.9	21.9	22.9	23.9	24.9	25.9	26.9
63....	18.8	19.8	20.8	21.8	22.8	23.8	24.8	25.8	26.8
64....	18.8	19.8	20.8	21.8	22.8	23.8	24.8	25.8	26.8
65....	18.7	19.7	20.7	21.7	22.7	23.7	24.7	25.7	26.7
66....	18.7	19.7	20.7	21.7	22.6	23.6	24.6	25.6	26.6
67....	18.6	19.6	20.6	21.6	22.6	23.6	24.6	25.6	26.6
68....	18.5	19.5	20.5	21.5	22.5	23.5	24.5	25.5	26.5
69....	18.5	19.5	20.5	21.5	22.4	23.4	24.4	25.4	26.4
70....	18.4	19.4	20.4	21.4	22.4	23.4	24.4	25.4	26.4
71....	18.4	19.4	20.4	21.4	22.3	23.3	24.3	25.3	26.3
72....	18.3	19.3	20.3	21.3	22.3	23.3	24.3	25.2	26.2
73....	18.3	19.2	20.2	21.2	22.2	23.2	24.2	25.2	26.2
74....	18.2	19.2	20.2	21.2	22.2	23.1	24.1	25.1	26.1
75....	18.2	19.1	20.1	21.1	22.1	23.1	24.1	25.1	26.0
76....	18.1	19.1	20.1	21.1	22.0	23.0	24.0	25.0	26.0
77....	18.0	19.0	20.0	21.0	22.0	23.0	24.0	25.0	25.9
78....	18.0	19.0	20.0	20.9	21.9	22.9	23.9	24.9	25.9
79....	17.9	18.9	19.9	20.9	21.8	22.8	23.8	24.8	25.8
80....	17.9	18.9	19.9	20.8	21.8	22.8	23.8	24.8	25.7
81....	17.8	18.8	19.8	20.8	21.7	22.7	23.7	24.7	25.7
82....	17.8	18.7	19.7	20.7	21.7	22.7	23.6	24.6	25.6
83....	17.7	18.7	19.7	20.6	21.6	22.6	23.6	24.6	25.5
84....	17.7	18.6	19.6	20.6	21.6	22.6	23.5	24.5	25.5
85....	17.6	18.6	19.5	20.5	21.5	22.5	23.5	24.5	25.4
86....	17.6	18.5	19.5	20.5	21.4	22.4	23.4	24.4	25.4
87....	17.5	18.4	19.4	20.4	21.4	22.4	23.3	24.3	25.3
88....	17.4	18.4	19.4	20.4	21.3	22.3	23.3	24.3	25.2
89....	17.4	18.3	19.3	20.3	21.3	22.2	23.2	24.2	25.2
90....	17.3	18.3	19.3	20.3	21.2	22.2	23.2	24.2	25.1
91....	17.3	18.2	19.2	20.2	21.2	22.1	23.1	24.1	25.1
92....	17.2	18.2	19.2	20.1	21.1	22.1	23.0	24.0	25.0
93....	17.2	18.1	19.1	20.1	21.0	22.0	23.0	24.0	24.9
94....	17.1	18.1	19.0	20.0	21.0	22.0	22.9	23.9	24.9
95....	17.1	18.0	19.0	20.0	20.9	21.9	22.9	23.8	24.8
96....	17.0	18.0	18.9	19.9	20.9	21.9	22.8	23.8	24.8
97....	17.0	17.9	18.9	19.9	20.8	21.8	22.8	23.7	24.7
98....	16.9	17.9	18.8	19.8	20.8	21.7	22.7	23.7	24.6
99....	16.8	17.8	18.8	19.8	20.7	21.7	22.7	23.6	24.6

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.								
	19	20	21	22	23	24	25	26	27
	Corresponding degrees A. P. I. at 60° F.								
100....	16.8	17.8	18.7	19.7	20.7	21.6	22.6	23.6	24.5
101....	16.7	17.7	18.7	19.6	20.6	21.6	22.5	23.5	24.5
102....	16.7	17.6	18.6	19.6	20.5	21.5	22.5	23.4	24.4
103....	16.6	17.6	18.6	19.5	20.5	21.5	22.4	23.4	24.4
104....	16.6	17.5	18.5	19.5	20.4	21.4	22.3	23.3	24.3
105....	16.5	17.5	18.5	19.4	20.4	21.3	22.3	23.3	24.2
106....	16.5	17.4	18.4	19.4	20.3	21.3	22.2	23.2	24.2
107....	16.4	17.4	18.4	19.3	20.3	21.2	22.2	23.2	24.1
108....	16.4	17.3	18.3	19.3	20.2	21.2	22.1	23.1	24.0
109....	16.3	17.3	18.3	19.2	20.2	21.1	22.1	23.0	24.0
110....	16.3	17.2	18.2	19.2	20.1	21.1	22.0	23.0	23.9
111....	16.2	17.2	18.1	19.1	20.1	21.0	22.0	22.9	23.9
112....	16.2	17.1	18.1	19.0	20.0	20.9	21.9	22.9	23.8
113....	16.1	17.1	18.0	19.0	19.9	20.9	21.8	22.8	23.7
114....	16.1	17.0	18.0	18.9	19.9	20.8	21.8	22.8	23.7
115....	16.0	17.0	17.9	18.9	19.8	20.8	21.7	22.7	23.6
116....	16.0	16.9	17.9	18.8	19.8	20.7	21.7	22.6	23.6
117....	15.9	16.9	17.8	18.8	19.7	20.7	21.6	22.6	23.5
118....	15.9	16.8	17.8	18.7	19.7	20.6	21.6	22.5	23.5
119....	15.8	16.8	17.7	18.7	19.6	20.6	21.5	22.5	23.4
120....	15.8	16.7	17.7	18.6	19.6	20.5	21.4	22.4	23.3
121....	15.7	16.6	17.6	18.5	19.5	20.4	21.4	22.3	23.3
122....	15.6	16.6	17.5	18.5	19.4	20.4	21.3	22.3	23.2
123....	15.6	16.5	17.5	18.4	19.4	20.3	21.3	22.2	23.2
124....	15.5	16.5	17.4	18.4	19.3	20.3	21.2	22.2	23.1
125....	15.5	16.4	17.4	18.3	19.3	20.2	21.2	22.1	23.1
126....	15.4	16.4	17.3	18.3	19.2	20.2	21.1	22.1	23.0
127....	15.4	16.3	17.3	18.2	19.2	20.1	21.0	22.0	22.9
128....	15.3	16.3	17.2	18.2	19.1	20.1	21.0	21.9	22.9
129....	15.3	16.2	17.2	18.1	19.1	20.0	20.9	21.9	22.8
130....	15.2	16.2	17.1	18.1	19.0	19.9	20.9	21.8	22.8
131....	15.2	16.1	17.0	18.0	18.9	19.9	20.8	21.8	22.7
132....	15.1	16.1	17.0	18.0	18.9	19.8	20.8	21.7	22.7
133....	15.1	16.0	16.9	17.9	18.8	19.8	20.7	21.7	22.6
134....	15.0	16.0	16.9	17.9	18.8	19.7	20.6	21.6	22.5
135....	15.0	15.9	16.8	17.8	18.7	19.7	20.6	21.6	22.5
136....	14.9	15.9	16.8	17.7	18.7	19.6	20.5	21.5	22.4
137....	14.9	15.8	16.7	17.7	18.6	19.6	20.5	21.4	22.4
138....	14.8	15.8	16.7	17.6	18.6	19.5	20.4	21.4	22.3
139....	14.8	15.7	16.6	17.6	18.5	19.4	20.4	21.3	22.2
140....	14.7	15.6	16.6	17.5	18.5	19.4	20.3	21.3	22.2
141....	14.7	15.6	16.5	17.5	18.4	19.3	20.3	21.2	22.1
142....	14.6	15.5	16.5	17.4	18.4	19.3	20.2	21.2	22.1
143....	14.6	15.5	16.4	17.4	18.3	19.2	20.2	21.1	22.0
144....	14.5	15.4	16.4	17.3	18.3	19.2	20.1	21.0	22.0
145....	14.5	15.4	16.3	17.3	18.2	19.1	20.0	21.0	21.9
146....	14.4	15.3	16.3	17.2	18.2	19.1	20.0	20.9	21.9
147....	14.4	15.3	16.2	17.2	18.1	19.0	19.9	20.9	21.8
148....	14.3	15.2	16.2	17.1	18.0	18.9	19.9	20.8	21.8
149....	14.3	15.2	16.1	17.0	18.0	18.9	19.8	20.8	21.7

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.								
	19	20	21	22	23	24	25	26	27
	Corresponding degrees A. P. I. at 60° F.								
150....	14.2	15.1	16.1	17.0	17.9	18.8	19.8	20.7	21.7
151....	14.2	15.1	16.0	16.9	17.9	18.8	19.7	20.7	21.6
152....	14.1	15.0	16.0	16.9	17.8	18.7	19.7	20.6	21.5
153....	14.1	15.0	15.9	16.8	17.8	18.7	19.6	20.6	21.5
154....	14.0	14.9	15.9	16.8	17.7	18.6	19.6	20.5	21.4
155....	14.0	14.9	15.8	16.7	17.7	18.6	19.5	20.5	21.4
156....	13.9	14.8	15.7	16.7	17.6	18.5	19.4	20.4	21.3
157....	13.8	14.8	15.7	16.6	17.6	18.5	19.4	20.3	21.3
158....	13.8	14.7	15.6	16.6	17.5	18.4	19.3	20.3	21.2
159....	13.7	14.7	15.6	16.5	17.4	18.4	19.3	20.2	21.1
160....	13.7	14.6	15.5	16.5	17.4	18.3	19.2	20.2	21.1
161....	13.6	14.6	15.5	16.4	17.3	18.3	19.2	20.1	21.0
162....	13.6	14.5	15.4	16.4	17.3	18.2	19.1	20.1	21.0
163....	13.5	14.5	15.4	16.3	17.2	18.2	19.1	20.0	20.9
164....	13.5	14.4	15.3	16.3	17.2	18.1	19.0	19.9	20.9
165....	13.4	14.4	15.3	16.2	17.1	18.0	18.9	19.9	20.8
166....	13.4	14.3	15.2	16.2	17.1	18.0	18.9	19.8	20.7
167....	13.3	14.3	15.2	16.1	17.0	17.9	18.8	19.8	20.7
168....	13.3	14.2	15.1	16.1	17.0	17.9	18.8	19.7	20.6
169....	13.3	14.2	15.1	16.0	16.9	17.8	18.7	19.7	20.6
170....	13.2	14.1	15.0	16.0	16.9	17.8	18.7	19.6	20.5
171....	13.2	14.1	15.0	15.9	16.8	17.7	18.6	19.6	20.5
172....	13.1	14.0	14.9	15.9	16.8	17.7	18.6	19.5	20.4
173....	13.1	14.0	14.9	15.8	16.7	17.6	18.5	19.5	20.4
174....	13.0	13.9	14.8	15.8	16.7	17.6	18.5	19.4	20.3
175....	13.0	13.9	14.8	15.7	16.6	17.5	18.4	19.3	20.3
176....	12.9	13.8	14.7	15.7	16.6	17.5	18.4	19.3	20.2
177....	12.9	13.8	14.7	15.6	16.5	17.4	18.3	19.2	20.1
178....	12.8	13.7	14.6	15.6	16.5	17.4	18.3	19.2	20.1
179....	12.8	13.7	14.6	15.5	16.4	17.3	18.2	19.1	20.0
180....	12.7	13.6	14.6	15.5	16.4	17.3	18.2	19.1	20.0
181....	12.7	13.6	14.5	15.4	16.3	17.2	18.1	19.0	19.9
182....	12.6	13.5	14.5	15.4	16.3	17.2	18.1	19.0	19.9
183....	12.6	13.5	14.4	15.3	16.2	17.1	18.0	18.9	19.8
184....	12.5	13.4	14.4	15.3	16.2	17.1	18.0	18.9	19.8
185....	12.5	13.4	14.3	15.2	16.1	17.0	17.9	18.8	19.7
186....	12.5	13.4	14.3	15.2	16.1	17.0	17.9	18.8	19.7
187....	12.4	13.3	14.2	15.1	16.0	16.9	17.8	18.7	19.6
188....	12.4	13.3	14.2	15.1	16.0	16.9	17.8	18.7	19.6
189....	12.3	13.2	14.1	15.0	15.9	16.8	17.7	18.6	19.5
190....	12.3	13.2	14.1	15.0	15.9	16.8	17.7	18.6	19.5
191....	12.2	13.1	14.0	14.9	15.8	16.7	17.6	18.5	19.4
192....	12.2	13.1	14.0	14.9	15.8	16.7	17.6	18.4	19.3
193....	12.1	13.0	13.9	14.8	15.7	16.6	17.5	18.4	19.3
194....	12.1	13.0	13.9	14.8	15.7	16.6	17.4	18.3	19.2
195....	12.0	12.9	13.8	14.7	15.6	16.5	17.4	18.3	19.2

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.								
	28	29	30	31	32	33	34	35	36
	Corresponding degrees A. P. I. at 60° F.								
0....	32.1	33.2	34.2	35.3	36.4	37.4	38.5	39.6	40.7
1....	32.0	33.1	34.1	35.2	36.3	37.3	38.4	39.5	40.6
2....	31.9	33.0	34.0	35.1	36.2	37.2	38.3	39.4	40.5
3....	31.8	32.9	34.0	35.0	36.1	37.2	38.2	39.3	40.4
4....	31.8	32.8	33.9	34.9	36.0	37.1	38.2	39.2	40.3
5....	31.7	32.8	33.8	34.9	36.0	37.0	38.1	39.2	40.2
6....	31.6	32.7	33.7	34.8	35.9	36.9	38.0	39.1	40.1
7....	31.6	32.6	33.7	34.7	35.8	36.8	37.9	39.0	40.1
8....	31.5	32.6	33.6	34.7	35.7	36.8	37.8	38.9	40.0
9....	31.4	32.5	33.5	34.6	35.7	36.7	37.8	38.9	39.9
10....	31.3	32.4	33.4	34.5	35.6	36.6	37.7	38.8	39.8
11....	31.3	32.3	33.4	34.4	35.5	36.5	37.6	38.7	39.7
12....	31.2	32.3	33.3	34.4	35.4	36.5	37.5	38.6	39.7
13....	31.1	32.2	33.2	34.3	35.3	36.4	37.5	38.5	39.6
14....	31.1	32.1	33.1	34.2	35.3	36.3	37.4	38.5	39.5
15....	31.0	32.0	33.1	34.1	35.2	36.2	37.3	38.4	39.4
16....	30.9	32.0	33.0	34.1	35.1	36.2	37.2	38.3	39.3
17....	30.9	31.9	32.9	34.0	35.0	36.1	37.1	38.2	39.3
18....	30.8	31.8	32.9	33.9	35.0	36.0	37.1	38.2	39.2
19....	30.7	31.8	32.8	33.8	34.9	36.0	37.0	38.1	39.1
20....	30.7	31.7	32.7	33.8	34.8	35.9	36.9	38.0	39.0
21....	30.6	31.6	32.6	33.7	34.7	35.8	36.8	37.9	39.0
22....	30.5	31.6	32.6	33.6	34.7	35.7	36.8	37.8	38.9
23....	30.4	31.5	32.5	33.6	34.6	35.7	36.7	37.8	38.8
24....	30.4	31.4	32.4	33.5	34.5	35.6	36.6	37.7	38.7
25....	30.3	31.4	32.4	33.4	34.5	35.5	36.5	37.6	38.6
26....	30.2	31.3	32.3	33.3	34.4	35.4	36.5	37.5	38.6
27....	30.2	31.2	32.2	33.3	34.3	35.3	36.4	37.4	38.5
28....	30.1	31.1	32.2	33.2	34.2	35.3	36.3	37.4	38.4
29....	30.0	31.1	32.1	33.1	34.2	35.2	36.2	37.3	38.3
30....	30.0	31.0	32.0	33.0	34.1	35.1	36.1	37.2	38.2
31....	29.9	30.9	31.9	33.0	34.0	35.0	36.1	37.1	38.2
32....	29.8	30.9	31.9	32.9	34.0	35.0	36.0	37.1	38.1
33....	29.8	30.8	31.8	32.8	33.9	34.9	35.9	37.0	38.0
34....	29.7	30.7	31.7	32.8	33.8	34.8	35.9	36.9	37.9
35....	29.6	30.7	31.7	32.7	33.7	34.8	35.8	36.8	37.9
36....	29.6	30.6	31.6	32.6	33.7	34.7	35.7	36.8	37.8
37....	29.5	30.5	31.5	32.6	33.6	34.6	35.6	36.7	37.7
38....	29.4	30.4	31.5	32.5	33.5	34.6	35.6	36.6	37.6
39....	29.4	30.4	31.4	32.4	33.5	34.5	35.5	36.5	37.6
40....	29.3	30.3	31.3	32.3	33.4	34.4	35.4	36.5	37.5
41....	29.2	30.3	31.3	32.3	33.3	34.3	35.4	36.4	37.4
42....	29.2	30.2	31.2	32.2	33.2	34.3	35.3	36.3	37.3
43....	29.1	30.1	31.1	32.1	33.2	34.2	35.2	36.2	37.2
44....	29.0	30.0	31.0	32.1	33.1	34.1	35.1	36.2	37.2
45....	29.0	30.0	31.0	32.0	33.0	34.1	35.1	36.1	37.1
46....	28.9	29.9	30.9	31.9	32.9	34.0	35.0	36.0	37.0
47....	28.8	29.8	30.8	31.9	32.9	33.9	34.9	36.0	37.0
48....	28.8	29.8	30.8	31.8	32.8	33.8	34.8	35.9	36.9
49....	28.7	29.7	30.7	31.7	32.8	33.8	34.8	35.8	36.8

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.								
	28	29	30	31	32	33	34	35	36
	Corresponding degrees A. P. I. at 60° F.								
50....	28.7	29.7	30.7	31.7	32.7	33.7	34.7	35.7	36.7
51....	28.6	29.6	30.6	31.6	32.6	33.6	34.7	35.7	36.7
52....	28.5	29.5	30.5	31.5	32.6	33.6	34.6	35.6	36.6
53....	28.5	29.5	30.5	31.5	32.5	33.5	34.5	35.5	36.5
54....	28.4	29.4	30.4	31.4	32.4	33.4	34.4	35.4	36.4
55....	28.3	29.3	30.3	31.3	32.3	33.4	34.4	35.4	36.4
56....	28.3	29.3	30.2	31.2	32.3	33.3	34.3	35.3	36.3
57....	28.2	29.2	30.2	31.2	32.2	33.2	34.2	35.2	36.2
58....	28.1	29.1	30.1	31.1	32.1	33.1	34.1	35.1	36.1
59....	28.1	29.1	30.0	31.0	32.1	33.1	34.1	35.1	36.1
60....	28.0	29.0	30.0	31.0	32.0	33.0	34.0	35.0	36.0
61....	27.9	28.9	29.9	30.9	31.9	32.9	33.9	34.9	35.9
62....	27.9	28.9	29.9	30.9	31.9	32.9	33.9	34.9	35.9
63....	27.8	28.8	29.8	30.8	31.8	32.8	33.8	34.8	35.8
64....	27.8	28.8	29.7	30.7	31.7	32.7	33.7	34.7	35.7
65....	27.7	28.7	29.7	30.7	31.7	32.7	33.7	34.7	35.6
66....	27.6	28.6	29.6	30.6	31.6	32.6	33.6	34.6	35.6
67....	27.6	28.5	29.5	30.5	31.5	32.5	33.5	34.5	35.5
68....	27.5	28.5	29.5	30.5	31.5	32.4	33.4	34.4	35.4
69....	27.4	28.4	29.4	30.4	31.4	32.4	33.4	34.4	35.3
70....	27.4	28.3	29.3	30.3	31.3	32.3	33.3	34.3	35.3
71....	27.3	28.3	29.3	30.2	31.2	32.2	33.2	34.2	35.2
72....	27.2	28.2	29.2	30.2	31.2	32.2	33.1	34.1	35.1
73....	27.2	28.2	29.1	30.1	31.1	32.1	33.1	34.1	35.0
74....	27.1	28.1	29.1	30.0	31.0	32.0	33.0	34.0	35.0
75....	27.0	28.0	29.0	30.0	31.0	31.9	32.9	33.9	34.9
76....	27.0	28.0	28.9	29.9	30.9	31.9	32.9	33.9	34.8
77....	26.9	27.9	28.9	29.9	30.9	31.8	32.8	33.8	34.8
78....	26.8	27.8	28.8	29.8	30.8	31.7	32.7	33.7	34.7
79....	26.8	27.8	28.7	29.7	30.7	31.7	32.6	33.6	34.6
80....	26.7	27.7	28.7	29.6	30.6	31.6	32.6	33.6	34.6
81....	26.7	27.6	28.6	29.6	30.6	31.5	32.5	33.5	34.5
82....	26.6	27.6	28.5	29.5	30.5	31.5	32.5	33.4	34.4
83....	26.5	27.5	28.5	29.5	30.4	31.4	32.4	33.4	34.3
84....	26.5	27.4	28.4	29.4	30.4	31.3	32.3	33.3	34.3
85....	26.4	27.4	28.4	29.3	30.3	31.3	32.2	33.2	34.2
86....	26.3	27.3	28.3	29.3	30.2	31.2	32.2	33.1	34.1
87....	26.3	27.3	28.2	29.2	30.2	31.1	32.1	33.1	34.1
88....	26.2	27.2	28.2	29.1	30.1	31.1	32.0	33.0	34.0
89....	26.2	27.1	28.1	29.1	30.1	31.0	32.0	33.0	33.9
90....	26.1	27.1	28.0	29.0	30.0	30.9	31.9	32.9	33.8
91....	26.0	27.0	28.0	28.9	29.9	30.9	31.8	32.8	33.8
92....	26.0	26.9	27.9	28.9	29.9	30.8	31.8	32.7	33.7
93....	25.9	26.9	27.9	28.8	29.8	30.7	31.7	32.7	33.6
94....	25.9	26.8	27.8	28.7	29.7	30.7	31.6	32.6	33.6
95....	25.8	26.8	27.7	28.7	29.7	30.6	31.6	32.6	33.5
96....	25.8	26.7	27.7	28.6	29.6	30.5	31.5	32.5	33.5
97....	25.7	26.6	27.6	28.6	29.5	30.5	31.5	32.4	33.4
98....	25.6	26.6	27.5	28.5	29.5	30.4	31.4	32.4	33.3
99....	25.6	26.5	27.5	28.4	29.4	30.4	31.3	32.3	33.3

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.								
	28	29	30	31	32	33	34	35	36
	Corresponding degrees A. P. I. at 60° F.								
100....	25.5	26.5	27.4	28.4	29.3	30.3	31.3	32.2	33.2
101....	25.4	26.4	27.3	28.3	29.3	30.2	31.2	32.2	33.1
102....	25.4	26.3	27.3	28.2	29.2	30.2	31.1	32.1	33.0
103....	25.3	26.3	27.2	28.2	29.1	30.1	31.0	32.0	32.9
104....	25.2	26.2	27.2	28.1	29.1	30.0	31.0	31.9	32.9
105....	25.2	26.1	27.1	28.0	29.0	30.0	30.9	31.9	32.8
106....	25.1	26.1	27.0	28.0	29.0	29.9	30.9	31.8	32.8
107....	25.1	26.0	27.0	27.9	28.9	29.8	30.8	31.7	32.7
108....	25.0	25.9	26.9	27.9	28.8	29.8	30.7	31.7	32.6
109....	24.9	25.9	26.9	27.8	28.8	29.7	30.7	31.6	32.6
110....	24.9	25.8	26.8	27.7	28.7	29.6	30.6	31.5	32.5
111....	24.8	25.8	26.7	27.7	28.6	29.6	30.5	31.5	32.4
112....	24.8	25.7	26.7	27.6	28.6	29.5	30.5	31.4	32.3
113....	24.7	25.6	26.6	27.5	28.5	29.4	30.4	31.3	32.3
114....	24.7	25.6	26.5	27.5	28.4	29.4	30.3	31.3	32.2
115....	24.6	25.5	26.5	27.4	28.4	29.3	30.3	31.2	32.1
116....	24.5	25.5	26.4	27.4	28.3	29.3	30.2	31.2	32.1
117....	24.5	25.4	26.4	27.3	28.3	29.2	30.1	31.1	32.0
118....	24.4	25.3	26.3	27.3	28.2	29.1	30.1	31.0	31.9
119....	24.4	25.3	26.3	27.2	28.2	29.1	30.0	31.0	31.9
120....	24.3	25.2	26.2	27.1	28.1	29.0	30.0	30.9	31.8
121....	24.2	25.2	26.1	27.1	28.0	28.9	29.9	30.8	31.7
122....	24.2	25.1	26.1	27.0	28.0	28.9	29.8	30.7	31.7
123....	24.1	25.1	26.0	26.9	27.9	28.8	29.8	30.7	31.6
124....	24.1	25.0	25.9	26.9	27.8	28.7	29.7	30.6	31.6
125....	24.0	24.9	25.9	26.8	27.8	28.7	29.6	30.6	31.5
126....	24.0	24.9	25.8	26.8	27.7	28.6	29.6	30.5	31.4
127....	23.9	24.8	25.8	26.7	27.6	28.6	29.5	30.4	31.3
128....	23.8	24.8	25.7	26.6	27.6	28.5	29.4	30.4	31.3
129....	23.8	24.7	25.6	26.6	27.5	28.4	29.4	30.3	31.2
130....	23.7	24.6	25.6	26.5	27.4	28.4	29.3	30.2	31.2
131....	23.6	24.6	25.5	26.4	27.4	28.3	29.2	30.2	31.1
132....	23.6	24.5	25.5	26.4	27.3	28.3	29.2	30.1	31.0
133....	23.5	24.5	25.4	26.3	27.3	28.2	29.1	30.1	31.0
134....	23.5	24.4	25.3	26.3	27.2	28.1	29.1	30.0	30.9
135....	23.4	24.4	25.3	26.2	27.1	28.1	29.0	29.9	30.8
136....	23.4	24.3	25.2	26.1	27.1	28.0	28.9	29.9	30.8
137....	23.3	24.2	25.2	26.1	27.0	27.9	28.9	29.8	30.7
138....	23.2	24.2	25.1	26.0	27.0	27.9	28.8	29.7	30.6
139....	23.2	24.1	25.0	26.0	26.9	27.8	28.7	29.7	30.6
140....	23.1	24.0	25.0	25.9	26.8	27.7	28.7	29.6	30.5
141....	23.1	24.0	24.9	25.8	26.8	27.7	28.6	29.5	30.4
142....	23.0	23.9	24.9	25.8	26.7	27.6	28.5	29.5	30.4
143....	23.0	23.9	24.8	25.7	26.6	27.6	28.5	29.4	30.3
144....	22.9	23.8	24.7	25.7	26.6	27.5	28.4	29.3	30.2
145....	22.9	23.8	24.7	25.6	26.5	27.4	28.4	29.3	30.2
146....	22.8	23.7	24.6	25.6	26.5	27.4	28.3	29.2	30.1
147....	22.7	23.6	24.6	25.5	26.4	27.3	28.3	29.2	30.1
148....	22.7	23.6	24.5	25.4	26.4	27.3	28.2	29.1	30.0
149....	22.6	23.5	24.5	25.4	26.3	27.2	28.1	29.1	30.0

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.								
	28	29	30	31	32	33	34	35	36
	Corresponding degrees A. P. I. at 60° F.								
150....	22.6	23.5	24.4	25.3	26.3	27.2	28.1	29.0	29.9
151....	22.5	23.4	24.4	25.3	26.2	27.1	28.0	28.9	29.8
152....	22.5	23.4	24.3	25.2	26.1	27.0	28.0	28.9	29.8
153....	22.4	23.3	24.3	25.2	26.1	27.0	27.9	28.8	29.7
154....	22.3	23.3	24.2	25.1	26.0	26.9	27.8	28.7	29.6
155....	22.3	23.2	24.1	25.0	25.9	26.9	27.8	28.7	29.6
156....	22.2	23.2	24.1	25.0	25.9	26.8	27.7	28.6	29.5
157....	22.2	23.1	24.0	24.9	25.8	26.7	27.6	28.5	29.4
158....	22.1	23.0	23.9	24.8	25.8	26.7	27.6	28.5	29.4
159....	22.1	23.0	23.9	24.8	25.7	26.6	27.5	28.4	29.3
160....	22.0	22.9	23.8	24.7	25.6	26.5	27.4	28.4	29.3
161....	21.9	22.9	23.8	24.7	25.6	26.5	27.4	28.3	29.2
162....	21.9	22.8	23.7	24.6	25.5	26.4	27.3	28.2	29.1
163....	21.8	22.7	23.7	24.6	25.5	26.4	27.3	28.2	29.1
164....	21.8	22.7	23.6	24.5	25.4	26.3	27.2	28.1	29.0
165....	21.7	22.6	23.5	24.4	25.3	26.2	27.1	28.0	28.9
166....	21.7	22.6	23.5	24.4	25.3	26.2	27.1	28.0	28.9
167....	21.6	22.5	23.4	24.3	25.2	26.1	27.0	27.9	28.8
168....	21.6	22.5	23.4	24.3	25.2	26.1	27.0	27.9	28.7
169....	21.5	22.4	23.3	24.2	25.1	26.0	26.9	27.8	28.7
170....	21.4	22.3	23.2	24.1	25.0	25.9	26.8	27.7	28.6
171....	21.4	22.3	23.2	24.1	25.0	25.9	26.8	27.7	28.6
172....	21.3	22.2	23.1	24.0	24.9	25.8	26.7	27.6	28.5
173....	21.3	22.2	23.1	24.0	24.9	25.8	26.7	27.6	28.5
174....	21.2	22.1	23.0	23.9	24.8	25.7	26.6	27.5	28.4
175....	21.2	22.1	22.9	23.8	24.7	25.6	26.5	27.4	28.3
176....	21.1	22.0	22.9	23.8	24.7	25.6	26.5	27.4	28.3
177....	21.0	21.9	22.8	23.7	24.6	25.5	26.4	27.3	28.2
178....	21.0	21.9	22.8	23.7	24.6	25.5	26.4	27.3	28.1
179....	20.9	21.8	22.7	23.6	24.5	25.4	26.3	27.2	28.1
180....	20.9	21.8	22.7	23.6	24.5	25.3	26.2	27.1	28.0
181....	20.8	21.7	22.6	23.5	24.4	25.3	26.2	27.1	28.0
182....	20.8	21.7	22.6	23.5	24.4	25.2	26.1	27.0	27.9
183....	20.7	21.6	22.5	23.4	24.3	25.2	26.1	27.0	27.8
184....	20.7	21.6	22.5	23.4	24.3	25.1	26.0	26.9	27.8
185....	20.6	21.5	22.4	23.3	24.2	25.1	25.9	26.8	27.7
186....	20.6	21.4	22.3	23.2	24.1	25.0	25.9	26.8	27.6
187....	20.5	21.4	22.3	23.2	24.1	25.0	25.8	26.7	27.6
188....	20.5	21.3	22.2	23.1	24.0	24.9	25.8	26.6	27.5
189....	20.4	21.3	22.2	23.1	24.0	24.8	25.7	26.6	27.5
190....	20.3	21.2	22.1	23.0	23.9	24.8	25.7	26.5	27.4
191....	20.3	21.2	22.1	22.9	23.8	24.7	25.6	26.5	27.3
192....	20.2	21.1	22.0	22.9	23.8	24.7	25.5	26.4	27.3
193....	20.2	21.1	21.9	22.8	23.7	24.6	25.5	26.4	27.2
194....	20.1	21.0	21.9	22.8	23.7	24.5	25.4	26.3	27.2
195....	20.1	21.0	21.8	22.7	23.6	24.5	25.4	26.3	27.1

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.								
	37	38	39	40	41	42	43	44	45
	Corresponding degrees A. P. I. at 60° F.								
0....	41.8	42.9	44.0	45.1	46.2	47.3	48.4	49.5	50.7
1....	41.7	42.8	43.9	45.0	46.1	47.2	48.3	49.4	50.6
2....	41.6	42.7	43.8	44.9	46.0	47.1	48.2	49.3	50.5
3....	41.5	42.6	43.7	44.8	45.9	47.0	48.1	49.2	50.4
4....	41.4	42.5	43.6	44.7	45.8	46.9	48.0	49.1	50.3
5....	41.3	42.4	43.5	44.6	45.7	46.8	47.9	49.0	50.1
6....	41.2	42.3	43.4	44.5	45.6	46.7	47.8	48.9	50.0
7....	41.1	42.2	43.3	44.4	45.5	46.6	47.7	48.8	49.9
8....	41.1	42.1	43.2	44.3	45.4	46.5	47.6	48.7	49.8
9....	41.0	42.1	43.1	44.2	45.3	46.4	47.5	48.6	49.7
10....	40.9	42.0	43.1	44.1	45.2	46.3	47.4	48.5	49.6
11....	40.8	41.9	43.0	44.0	45.1	46.2	47.3	48.4	49.5
12....	40.7	41.8	42.9	43.9	45.0	46.1	47.2	48.3	49.4
13....	40.6	41.7	42.8	43.9	45.0	46.1	47.1	48.2	49.3
14....	40.6	41.6	42.7	43 8	44.9	46.0	47.0	48.1	49.2
15....	40.5	41.6	42.6	43.7	44.8	45.9	46.9	48.0	49.1
16....	40.4	41.5	42.5	43.6	44.7	45.8	46.8	47.9	49.0
17....	40.3	41.4	42.5	43.5	44.6	45.7	46.8	47.8	48.9
18....	40.3	41.3	42.4	43.4	44.5	45.6	46.7	47.7	48.8
19....	40.2	41.2	42.3	43.4	44.4	45.5	46.6	47.7	48.7
20....	40.1	41.2	42.2	43.3	44.3	45.4	46.5	47.6	48.7
21....	40.0	41.1	42.1	43.2	44.3	45.3	46.4	47.5	48.6
22....	39.9	41.0	42.1	43.1	44.2	45.2	46.3	47.4	48.5
23....	39.9	40.9	42.0	43.0	44.1	45.2	46.2	47.3	48.4
24....	39.8	40.8	41.9	42.9	44.0	45.1	46.1	47.2	48.3
25....	39.7	40.7	41.8	42.8	43.9	45.0	46.0	47.1	48.2
26....	39.6	40.7	41.7	42.8	43.8	44.9	45.9	47.0	48.1
27....	39.5	40.6	41.6	42.7	43.7	44.8	45.9	46.9	48.0
28....	39.4	40.5	41.5	42.6	43.6	44.7	45.8	46.8	47.9
29....	39.4	40.4	41.5	42.5	43.6	44.6	45.7	46.7	47.8
30....	39.3	40.3	41.4	42.4	43.5	44.5	45.6	46.6	47.7
31....	39.2	40.3	41.3	42.4	43.4	44.5	45.5	46.6	47.6
32....	39.1	40.2	41.2	42.3	43.3	44.4	45.4	46.5	47.5
33....	39.0	40.1	41.1	42.2	43.2	44.3	45.3	46.4	47.4
34....	39.0	40.0	41.1	42.1	43.1	44.2	45.2	46.3	47.3
35....	38.9	40.0	41.0	42.0	43.1	44.1	45.2	46.2	47.2
36....	38.8	39.9	40.9	41.9	43.0	44.0	45.1	46.1	47.2
37....	38.7	39.8	40.8	41.8	42.9	43.9	45.0	46.0	47.1
38....	38.7	39.7	40.7	41.8	42.8	43.9	44.9	45.9	47.0
39....	38.6	39.6	40.7	41.7	42.7	43.8	44.8	45.8	46.9
40....	38.5	39.5	40.6	41.6	42.6	43.7	44.7	45.7	46.8
41....	38.4	39.4	40.5	41.5	42.5	43.6	44.6	45.6	46.7
42....	38.3	39.4	40.4	41.4	42.5	43.5	44.5	45.6	46.6
43....	38.2	39.3	40.3	41.3	42.4	43.4	44.4	45.5	46.5
44....	38.2	39.2	40.3	41.3	42.3	43.3	44.4	45.4	46.4
45....	38.1	39.2	40.2	41.2	42.2	43.3	44.3	45.3	46.3
46....	38.1	39.1	40.1	41.1	42.1	43.2	44.2	45.2	46.2
47....	38.0	39.0	40.0	41.0	42.0	43.1	44.1	45.1	46.1
48....	37.9	38.9	40.0	41.0	42.0	43.0	44.0	45.0	46.1
49....	37.8	38.8	39.9	40.9	41.9	42.9	43.9	44.9	46.0

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.								
	37	38	39	40	41	42	43	44	45
	Corresponding degrees A. P. I. at 60° F.								
50....	37.7	38.8	39.8	40.8	41.8	42.8	43.8	44.8	45.9
51....	37.7	38.7	39.7	40.7	41.7	42.7	43.7	44.7	45.8
52....	37.6	38.6	39.6	40.6	41.6	42.7	43.7	44.7	45.7
53....	37.5	38.5	39.6	40.6	41.6	42.6	43.6	44.6	45.6
54....	37.5	38.5	39.5	40.5	41.5	42.5	43.5	44.5	45.5
55. ..	37.4	38.4	39.4	40.4	41.4	42.4	43.4	44.4	45.4
56....	37.3	38.3	39.3	40.3	41.3	42.3	43.3	44.3	45.4
57....	37.2	38.2	39.2	40.2	41.2	42.3	43.3	44.3	45.3
58....	37.1	38.1	39.2	40.2	41.2	42.2	43.2	44.2	45.2
59....	37.1	38.1	39.1	40.1	41.1	42.1	43.1	44.1	45.1
60....	37.0	38.0	39.0	40.0	41.0	42.0	43.0	44.0	45.0
61....	36.9	37.9	38.9	39.9	40.9	41.9	42.9	43.9	44.9
62....	36.9	37.9	38.9	39.8	40.8	41.9	42.8	43.8	44.8
63....	36.8	37.8	38.8	39.8	40.8	41.8	42.8	43.7	44.7
64....	36.7	37.7	38.7	39.7	40.7	41.7	42.7	43.7	44.6
65....	36.6	37.6	38.6	39.6	40.6	41.6	42.6	43.6	44.6
66....	36.6	37.6	38.6	39.5	40.5	41.5	42.5	43.5	44.5
67....	36.5	37.5	38.5	39.5	40.5	41.5	42.4	43.4	44.4
68....	36.4	37.4	38.4	39.4	40.4	41.4	42.3	43.3	44.3
69....	36.3	37.3	38.3	39.3	40.3	41.3	42.2	43.2	44.2
70....	36.2	37.2	38.2	39.2	40.2	41.2	42.2	43.2	44.1
71....	36.2	37.2	38.2	39.2	40.1	41.1	42.1	43.1	44.1
72....	36.1	37.1	38.1	39.1	40.1	41.1	42.0	43.0	44.0
73....	36.0	37.0	38.0	39.0	40.0	41.0	41.9	42.9	43.9
74....	36.0	36.9	37.9	38.9	39.9	40.9	41.8	42.8	43.8
75....	35.9	36.9	37.9	38.8	39.8	40.8	41.8	42.7	43.7
76....	35.8	36.8	37.8	38.8	39.7	40.7	41.7	42.7	43.6
77....	35.7	36.7	37.7	38.7	39.7	40.7	41.6	42.6	43.6
78....	35.7	36.7	37.6	38.6	39.6	40.6	41.5	42.5	43.5
79....	35.6	36.6	37.6	38.5	39.5	40.5	41.4	42.4	43.4
80....	35.5	36.5	37.5	38.4	39.4	40.4	41.3	42.3	43.3
81....	35.4	36.4	37.4	38.4	39.3	40.3	41.3	42.2	43.2
82....	35.4	36.4	37.3	38.3	39.3	40.3	41.2	42.2	43.1
83....	35.3	36.3	37.2	38.2	39.2	40.2	41.1	42.1	43.1
84....	35.2	36.2	37.2	38.1	39.1	40.1	41.0	42.0	43.0
85....	35.1	36.1	37.1	38.1	39.0	40.0	41.0	41.9	42.9
86....	35.1	36.1	37.0	38.0	38.9	39.9	40.9	41.8	42.8
87....	35.0	36.0	37.0	37.9	38.9	39.9	40.8	41.8	42.7
88....	34.9	35.9	36.9	37.9	38.8	39.8	40.7	41.7	42.6
89....	34.9	35.9	36.8	37.8	38.7	39.7	40.6	41.6	42.5
90....	34.8	35.8	36.7	37.7	38.7	39.6	40.6	41.5	42.5
91....	34.7	35.7	36.7	37.6	38.6	39.5	40.5	41.4	42.4
92....	34.7	35.6	36.6	37.6	38.5	39.5	40.4	41.4	42.3
93....	34.6	35.6	36.5	37.5	38.4	39.4	40.3	41.3	42.2
94....	34.5	35.5	36.5	37.4	38.4	39.3	40.3	41.2	42.2
95....	34.5	35.4	36.4	37.3	38.3	39.2	40.2	41.1	42.1
96....	34.4	35.4	36.3	37.3	38.2	39.2	40.1	41.1	42.0
97....	34.3	35.3	36.2	37.2	38.2	39.1	40.1	41.0	41.9
98....	34.3	35.2	36.2	37.1	38.1	39.0	40.0	40.9	41.9
99....	34.2	35.2	36.1	37.1	38.0	39.0	39.9	40.8	41.8

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.								
	37	38	39	40	41	42	43	44	45
	Corresponding degrees A. P. I. at 60° F.								
100....	34.1	35.1	36.1	37.0	37.9	38.9	39.8	40.7	41.7
101....	34.1	35.0	36.0	36.9	37.9	38.8	39.7	40.7	41.6
102....	34.0	34.9	35.9	36.8	37.8	38.7	39.7	40.6	41.5
103....	33.9	34.9	35.8	36.7	37.7	38.6	39.6	40.5	41.5
104....	33.8	34.8	35.7	36.7	37.6	38.6	39.5	40.4	41.4
105....	33.8	34.7	35.7	36.6	37.6	38.5	39.4	40.4	41.3
106....	33.7	34.7	35.6	36.5	37.5	38.4	39.3	40.3	41.2
107....	33.6	34.6	35.5	36.5	37.4	38.4	39.3	40.2	41.2
108....	33.6	34.5	35.5	36.4	37.3	38.3	39.2	40.1	41.1
109....	33.5	34.4	35.4	36.3	37.3	38.2	39.1	40.1	41.0
110....	33.4	34.4	35.3	36.2	37.2	38.1	39.0	40.0	40.9
111....	33.4	34.3	35.2	36.2	37.1	38.1	39.0	39.9	40.8
112....	33.3	34.2	35.2	36.1	37.0	38.0	38.9	39.8	40.8
113....	33.2	34.1	35.1	36.0	36.9	37.9	38.8	39.7	40.7
114....	33.1	34.1	35.0	36.0	36.9	37.8	38.8	39.7	40.6
115....	33.1	34.0	34.9	35.9	36.8	37.8	38.7	39.6	40.5
116....	33.0	34.0	34.9	35.8	36.7	37.7	38.6	39.5	40.4
117....	32.9	33.9	34.8	35.7	36.7	37.6	38.5	39.4	40.4
118....	32.9	33.8	34.7	35.7	36.6	37.5	38.4	39.4	40.3
119....	32.8	33.7	34.7	35.6	36.5	37.5	38.4	39.3	40.2
120....	32.7	33.7	34.6	35.5	36.5	37.4	38.3	39.2	40.2
121....	32.7	33.6	34.5	35.5	36.4	37.3	38.2	39.1	40.1
122....	32.6	33.5	34.5	35.4	36.3	37.2	38.1	39.1	40.0
123....	32.5	33.5	34.4	35.3	36.2	37.2	38.1	39.0	39.9
124....	32.5	33.4	34.3	35.3	36.2	37.1	38.0	38.9	39.8
125....	32.4	33.3	34.3	35.2	36.1	37.0	37.9	38.9	39.8
126....	32.3	33.3	34.2	35.1	36.0	37.0	37.9	38.8	39.7
127....	32.3	33.2	34.1	35.1	36.0	36.9	37.8	38.7	39.6
128....	32.2	33.1	34.1	35.0	35.9	36.8	37.7	38.6	39.6
129....	32.1	33.1	34.0	34.9	35.8	36.7	37.7	38.6	39.5
130....	32.1	33.0	33.9	34.8	35.8	36.7	37.6	38.5	39.4
131....	32.0	32.9	33.9	34.8	35.7	36.6	37.5	38.4	39.3
132....	31.9	32.9	33.8	34.7	35.6	36.5	37.4	38.4	39.3
133....	31.9	32.8	33.7	34.6	35.6	36.5	37.4	38.3	39.2
134....	31.8	32.7	33.6	34.6	35.5	36.4	37.3	38.2	39.1
135....	31.7	32.7	33.6	34.5	35.4	36.3	37.2	38.1	39.0
136....	31.7	32.6	33.5	34.5	35.4	36.3	37.2	38.1	39.0
137....	31.6	32.6	33.5	34.4	35.3	36.2	37.1	38.0	38.9
138....	31.6	32.5	33.4	34.3	35.2	36.1	37.0	37.9	38.8
139....	31.5	32.4	33.3	34.2	35.1	36.0	36.9	37.8	38.7
140....	31.4	32.3	33.2	34.2	35.1	36.0	36.9	37.8	38.7
141....	31.3	32.3	33.2	34.1	35.0	35.9	36.8	37.7	38.6
142....	31.3	32.2	33.1	34.0	34.9	35.8	36.7	37.6	38.5
143....	31.2	32.1	33.0	34.0	34.9	35.8	36.6	37.5	38.4
144....	31.2	32.1	33.0	33.9	34.8	35.7	36.6	37.5	38.3
145....	31.1	32.0	32.9	33.8	34.7	35.6	36.5	37.4	38.3
146....	31.0	32.0	32.9	33.8	34.7	35.6	36.4	37.3	38.2
147....	31.0	31.9	32.8	33.7	34.6	35.5	36.3	37.2	38.1
148....	30.9	31.8	32.7	33.6	34.5	35.4	36.3	37.2	38.1
149....	30.9	31.8	32.7	33.6	34.5	35.4	36.2	37.1	38.0

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.								
	37	38	39	40	41	42	43	44	45
	Corresponding degrees A. P. I. at 60° F.								
150....	30.8	31.7	32.6	33.5	34.4	35.3	36.1	37.0	37.9
151....	30.7	31.6	32.5						
152....	30.7	31.6	32.5						
153....	30.6	31.5	32.4						
154....	30.5	31.4	32.3						
155....	30.5	31.4	32.3						
156....	30.4	31.3	32.2						
157....	30.3	31.2	32.1						
158....	30.3	31.2	32.1						
159....	30.2	31.1	32.0						
160....	30.2	31.1	31.9						
161....	30.1	31.0	31.9						
162....	30.0	30.9	31.8						
163....	30.0	30.9	31.7						
164....	29.9	30.8	31.7						
165....	29.8	30.7	31.6						
166....	29.8	30.7	31.6						
167....	29.7	30.6	31.5						
168....	29.6	30.5	31.4						
169....	29.6	30.5	31.3						
170....	29.5	30.4	31.3						
171....	29.5	30.4	31.2						
172....	29.4	30.3	31.2						
173....	29.3	30.2	31.1						
174....	29.3	30.2	31.0						
175....	29.2	30.1	31.0						
176....	29.1	30.0	30.9						
177....	29.1	30.0	30.9						
178....	29.0	29.9	30.8						
179....	29.0	29.9	30.7						
180....	28.9	29.8	30.7						
181....	28.8	29.7	30.6						
182....	28.8	29.7	30.5						
183....	28.7	29.6	30.5						
184....	28.6	29.5	30.4						
185....	28.6	29.5	30.3						
186....	28.5	29.4	30.3						
187....	28.5	29.3	30.2						
188....	28.4	29.3	30.1						
189....	28.3	29.2	30.1						
190....	28.3	29.1	30.0						
191....	28.2	29.1	30.0						
192....	28.2	29.0	29.9						
193....	28.1	29.0	29.8						
194....	28.0	28.9	29.8						
195....	28.0	28.9	29.7						

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.								
	46	47	48	49	50	51	52	53	54
	Corresponding degrees A. P. I. at 60° F.								
0....	51.8	52.9	54.1	55.2	56.3	57.5	58.6	59.7	60.8
1....	51.7	52.8	54.0	55.1	56.2	57.4	58.5	59.6	60.7
2....	51.6	52.7	53.8	55.0	56.1	57.2	58.4	59.5	60.6
3....	51.5	52.6	53.7	54.9	56.0	57.1	58.2	59.3	60.4
4....	51.4	52.5	53.6	54.7	55.8	57.0	58.1	59.2	60.3
5....	51.3	52.4	53.5	54.6	55.7	56.9	58.0	59.1	60.2
6....	51.2	52.3	53.4	54.5	55.6	56.8	57.9	59.0	60.1
7....	51.1	52.2	53.3	54.4	55.5	56.6	57.7	58.8	59.9
8....	51.0	52.1	53.2	54.3	55.4	56.5	57.6	58.7	59.8
9....	50.9	52.0	53.1	54.2	55.3	56.4	57.5	58.6	59.7
10....	50.8	51.9	53.0	54.1	55.2	56.3	57.4	58.5	59.6
11....	50.7	51.8	52.9	54.0	55.1	56.2	57.3	58.4	59.5
12....	50.5	51.6	52.8	53.9	55.0	56.1	57.2	58.3	59.4
13....	50.4	51.5	52.6	53.7	54.8	55.9	57.0	58.1	59.2
14....	50.3	51.4	52.5	53.6	54.7	55.8	56.9	58.0	59.1
15....	50.2	51.3	52.4	53.5	54.6	55.7	56.8	57.9	59.0
16....	50.1	51.2	52.3	53.4	54.5	55.6	56.7	57.8	58.9
17....	50.0	51.1	52.2	53.3	54.4	55.5	56.6	57.6	58.7
18....	49.9	51.0	52.1	53.2	54.3	55.4	56.5	57.5	58.6
19....	49.8	50.9	52.0	53.1	54.2	55.3	56.3	57.4	58.5
20....	49.7	50.8	51.9	53.0	54.1	55.2	56.2	57.3	58.4
21....	49.6	50.7	51.8	52.9	54.0	55.1	56.1	57.2	58.3
22....	49.5	50.6	51.7	52.8	53.9	54.9	56.0	57.1	58.2
23....	49.4	50.5	51.6	52.7	53.8	54.8	55.9	57.0	58.0
24....	49.3	50.4	51.5	52.6	53.6	54.7	55.8	56.9	57.9
25....	49.2	50.3	51.4	52.5	53.5	54.6	55.7	56.8	57.8
26....	49.1	50.2	51.3	52.4	53.4	54.5	55.6	56.6	57.7
27....	49.0	50.1	51.2	52.3	53.3	54.4	55.5	56.5	57.6
28....	49.0	50.0	51.1	52.2	53.2	54.3	55.4	56.4	57.5
29....	48.9	49.9	51.0	52.1	53.1	54.2	55.3	56.3	57.4
30....	48.8	49.8	50.9	52.0	53.0	54.1	55.1	56.2	57.2
31....	48.7	49.7	50.8	51.9	52.9	54.0	55.0	56.1	57.1
32....	48.6	49.6	50.7	51.7	52.8	53.9	54.9	56.0	57.0
33....	48.5	49.5	50.6	51.6	52.7	53.8	54.8	55.9	56.9
34....	48.4	49.4	50.5	51.5	52.6	53.7	54.7	55.8	56.8
35....	48.3	49.3	50.4	51.4	52.5	53.5	54.6	55.6	56.7
36....	48.2	49.2	50.3	51.3	52.4	53.4	54.5	55.5	56.6
37....	48.1	49.1	50.2	51.2	52.3	53.3	54.4	55.4	56.5
38....	48.0	49.0	50.1	51.1	52.2	53.2	54.3	55.3	56.4
39....	47.9	49.0	50.0	51.0	52.1	53.1	54.2	55.2	56.2
40....	47.8	48.9	49.9	50.9	52.0	53.0	54.1	55.1	56.1
41....	47.7	48.8	49.8	50.8	51.9	52.9	54.0	55.0	56.0
42....	47.6	48.7	49.7	50.8	51.8	52.8	53.8	54.9	55.9
43....	47.5	48.6	49.6	50.7	51.7	52.7	53.7	54.8	55.8
44....	47.5	48.5	49.5	50.6	51.6	52.6	53.6	54.7	55.7
45....	47.4	48.4	49.4	50.5	51.5	52.5	53.5	54.6	55.6
46....	47.3	48.3	49.3	50.4	51.4	52.4	53.4	54.5	55.5
47....	47.2	48.2	49.2	50.3	51.3	52.3	53.3	54.3	55.4
48....	47.1	48.1	49.1	50.2	51.2	52.2	53.2	54.2	55.3
49....	47.0	48.0	49.0	50.1	51.1	52.1	53.1	54.1	55.2

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.								
	46	47	48	49	50	51	52	53	54
	Corresponding degrees A. P. I. at 60° F.								
50....	46.9	47.9	48.9	50.0	51.0	52.0	53.0	54.0	55.1
51....	46.8	47.8	48.8	49.9	50.9	51.9	52.9	53.9	55.0
52....	46.7	47.7	48.7	49.8	50.8	51.8	52.8	53.8	54.9
53....	46.6	47.6	48.6	49.7	50.7	51.7	52.7	53.7	54.7
54....	46.5	47.5	48.5	49.6	50.6	51.6	52.6	53.6	54.6
55....	46.4	47.5	48.5	49.5	50.5	51.5	52.5	53.5	54.5
56....	46.4	47.4	48.4	49.4	50.4	51.4	52.4	53.4	54.4
57....	46.3	47.3	48.3	49.3	50.3	51.3	52.3	53.3	54.3
58....	46.2	47.2	48.2	49.2	50.2	51.2	52.2	53.2	54.2
59....	46.1	47.1	48.1	49.1	50.1	51.1	52.1	53.1	54.1
60....	46.0	47.0	48.0	49.0	50.0	51.0	52.0	53.0	54.0
61....	45.9	46.9	47.9	48.9	49.9	50.9	51.9	52.9	53.9
62....	45.8	46.8	47.8	48.8	49.8	50.8	51.8	52.8	53.8
63....	45.7	46.7	47.7	48.7	49.7	50.7	51.7	52.7	53.7
64....	45.6	46.6	47.6	48.6	49.6	50.6	51.6	52.6	53.6
65....	45.6	46.6	47.5	48.5	49.5	50.5	51.5	52.5	53.5
66....	45.5	46.5	47.5	48.4	49.4	50.4	51.4	52.4	53.4
67....	45.4	46.4	47.4	48.3	49.3	50.3	51.3	52.3	53.3
68....	45.3	46.3	47.3	48.2	49.2	50.2	51.2	52.2	53.2
69....	45.2	46.2	47.2	48.2	49.1	50.1	51.1	52.1	53.1
70....	45.1	46.1	47.1	48.1	49.0	50.0	51.0	52.0	53.0
71....	45.0	46.0	47.0	48.0	49.0	50.0	50.9	51.9	52.9
72....	45.0	45.9	46.9	47.9	48.9	49.9	50.8	51.8	52.8
73....	44.9	45.8	46.8	47.8	48.8	49.8	50.7	51.7	52.7
74....	44.8	45.7	46.7	47.7	48.7	49.7	50.6	51.6	52.6
75....	44.7	45.7	46.6	47.6	48.6	49.6	50.5	51.5	52.5
76....	44.6	45.6	46.6	47.5	48.5	49.5	50.4	51.4	52.4
77....	44.5	45.5	46.5	47.5	48.4	49.4	50.4	51.3	52.3
78....	44.4	45.4	46.4	47.4	48.3	49.3	50.3	51.2	52.2
79....	44.4	45.3	46.3	47.3	48.2	49.2	50.2	51.1	52.1
80....	44.3	45.2	46.2	47.2	48.1	49.1	50.1	51.0	52.0
81....	44.2	45.1	46.1	47.1	48.0	49.0	50.0	50.9	51.9
82....	44.1	45.1	46.0	47.0	48.0	48.9	49.9	50.8	51.8
83....	44.0	45.0	46.0	46.9	47.9	48.8	49.8	50.8	51.7
84....	43.9	44.9	45.9	46.8	47.8	48.8	49.7	50.7	51.6
85....	43.8	44.8	45.8	46.7	47.7	48.7	49.6	50.6	51.5
86....	43.7	44.7	45.7	46.6	47.6	48.6	49.5	50.5	51.4
87....	43.7	44.6	45.6	46.6	47.5	48.5	49.4	50.4	51.3
88....	43.6	44.5	45.5	46.5	47.4	48.4	49.3	50.3	51.2
89....	43.5	44.5	45.4	46.4	47.3	48.3	49.2	50.2	51.1
90....	43.4	44.4	45.4	46.3	47.2	48.2	49.1	50.1	51.0
91....	43.3	44.3	45.3	46.2	47.2	48.1	49.0	50.0	50.9
92....	43.3	44.2	45.2	46.1	47.1	48.0	48.9	49.9	50.8
93....	43.2	44.1	45.1	46.0	47.0	47.9	48.8	49.8	50.7
94....	43.1	44.1	45.0	46.0	46.9	47.8	48.8	49.7	50.7
95....	43.0	44.0	44.9	45.9	46.8	47.8	48.7	49.6	50.6
96....	43.0	43.9	44.8	45.8	46.7	47.7	48.6	49.5	50.5
97....	42.9	43.8	44.8	45.7	46.6	47.6	48.5	49.4	50.4
98....	42.8	43.7	44.7	45.6	46.6	47.5	48.4	49.4	50.3
99....	42.7	43.7	44.6	45.6	46.5	47.4	48.3	49.3	50.2

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.								
	46	47	48	49	50	51	52	53	54
	Corresponding degrees A. P. I. at 60° F.								
100....	42.6	43.6	44.5	45.5	46.4	47.3	48.2	49.2	50.1
101....	42.5	43.5	44.4	45.4	46.3	47.2	48.1	49.1	50.0
102....	42.5	43.4	44.3	45.3	46.2	47.1	48.0	49.0	49.9
103....	42.4	43.3	44.3	45.2	46.1	47.0	48.0	48.9	49.8
104....	42.3	43.3	44.2	45.1	46.0	47.0	47.9	48.8	49.7
105....	42.2	43.2	44.1	45.0	46.0	46.9	47.8	48.7	49.6
106....	42.1	43.1	44.0	44.9	45.9	46.8	47.7	48.6	49.5
107....	42.1	43.0	43.9	44.8	45.8	46.7	47.6	48.5	49.4
108....	42.0	42.9	43.8	44.8	45.7	46.6	47.5	48.4	49.3
109....	41.9	42.8	43.7	44.7	45.6	46.5	47.4	48.3	49.2
110....	41.8	42.8	43.7	44.6	45.5	46.4	47.3	48.2	49.2
111....	41.8	42.7	43.6	44.5	45.4	46.4	47.3	48.2	49.1
112....	41.7	42.6	43.5	44.4	45.4	46.3	47.2	48.1	49.0
113....	41.6	42.5	43.4	44.4	45.3	46.2	47.1	48.0	48.9
114....	41.5	42.4	43.3	44.3	45.2	46.1	47.0	47.9	48.8
115....	41.4	42.4	43.3	44.2	45.1	46.0	46.9	47.8	48.7
116....	41.3	42.3	43.2	44.1	45.0	45.9	46.8	47.7	48.6
117....	41.3	42.2	43.1	44.0	45.0	45.8	46.7	47.6	48.5
118....	41.2	42.1	43.0	44.0	44.9	45.8	46.7	47.6	48.5
119....	41.1	42.1	43.0	43.9	44.8	45.7	46.6	47.5	48.4
120....	41.1	42.0	42.9	43.8	44.7	45.6	46.5	47.4	48.3
121....	41.0	41.9	42.8	43.7	44.6	45.5	46.4	47.3	48.2
122....	40.9	41.8	42.7	43.6	44.5	45.4	46.3	47.2	48.1
123....	40.8	41.7	42.6	43.6	44.5	45.4	46.2	47.1	48.0
124....	40.7	41.6	42.5	43.5	44.4	45.3	46.2	47.0	47.9
125....	40.7	41.6	42.5	43.4	44.3	45.2	46.1	47.0	47.8
126....	40.6	41.5	42.4	43.3					
127....	40.5	41.4	42.3	43.3					
128....	40.5	41.4	42.3	43.2					
129....	40.4	41.3	42.2	43.1					
130....	40.3	41.2	42.1	43.0					
131....	40.2	41.1	42.0	42.9					
132....	40.2	41.1	42.0	42.9					
133....	40.1	41.0	41.9	42.8					
134....	40.0	40.9	41.8	42.7					
135....	39.9	40.8	41.7	42.6					
136....	39.9	40.7	41.6	42.5					
137....	39.8	40.7	41.5	42.4					
138....	39.7	40.6	41.5	42.4					
139....	39.6	40.5	41.4	42.3					
140....	39.5	40.4	41.3	42.2					
141....	39.5	40.4	41.2	42.1					
142....	39.4	40.3	41.2	42.1					
143....	39.3	40.2	41.1	42.0					
144....	39.2	40.1	41.0	41.9					
145....	39.2	40.1	40.9	41.8					
146....	39.1	40.0	40.9	41.8					
147....	39.0	39.9	40.8	41.7					
148....	39.0	39.8	40.7	41.6					
149....	38.9	39.8	40.6	41.5					
150....	38.8	39.7	40.6	41.5					

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.								
	55	56	57	58	59	60	61	62	63
	Corresponding degrees A. P. I. at 60° F.								
0....	61.9	63.1	64.2	65.3	66.4	67.6	68.7	69.8	70.9
1....	61.8	62.9	64.0	65.2	66.3	67.4	68.5	69.7	70.8
2....	61.7	62.8	63.9	65.0	66.2	67.3	68.4	69.5	70.6
3....	61.5	62.6	63.8	64.9	66.0	67.1	68.2	69.4	70.5
4....	61.4	62.5	63.6	64.8	65.9	67.0	68.1	69.2	70.4
5....	61.3	62.4	63.5	64.6	65.8	66.9	68.0	69.1	70.2
6....	61.2	62.3	63.4	64.5	65.6	66.7	67.9	69.0	70.1
7....	61.0	62.2	63.3	64.4	65.5	66.6	67.7	68.8	70.0
8....	60.9	62.0	63.1	64.2	65 4	66.5	67.6	68.7	69.8
9....	60.8	61.9	63.0	64.1	65.2	66.3	67.4	68.6	69.7
10....	60.7	61.8	62.9	64.0	65.1	66.2	67.3	68.4	69.5
11....	60.6	61.7	62.8	63.9	65.0	66.0	67.2	68.3	69.4
12....	60.4	61.5	62.6	63.7	64.8	65.9	67.0	68.1	69.2
13....	60.3	61.4	62.5	63 6	64.7	65.8	66.9	68.0	69.1
14....	60.2	61.3	62.4	63.5	64.6	65.7	66.8	67.9	69.0
15....	60.1	61.2	62.3	63.4	64.4	65.5	66.6	67.7	68.8
16....	59.9	61.0	62.1	63.2	64.3	65.4	66.5	67.6	68.7
17....	59.8	60.9	62.0	63.1	64.2	65.3	66.4	67.5	68.6
18....	59.7	60.8	61.9	63.0	64.0	65.1	66.2	67.3	68.4
19....	59.6	60.7	61.8	62.8	63.9	65.0	66.1	67.2	68.3
20....	59.5	60.5	61.6	62.7	63.8	64.9	66.0	67.1	68.2
21....	59.4	60.4	61.5	62.6	63.7	64.8	65.8	66.9	68.0
22....	59.2	60.3	61.4	62.5	63.5	64.6	65.7	66.8	67.9
23....	59.1	60.2	61.3	62.4	63.4	64.5	65.6	66.7	67.7
24....	59.0	60.1	61.2	62.2	63.3	64.4	65.4	66.5	67.6
25....	58.9	60.0	61.0	62.1	63.2	64.2	65.3	66.4	67.5
26....	58.8	59.8	60.9	62.0	63.0	64.1	65.2	66.3	67.3
27....	58.7	59.7	60.8	61.9	62.9	64.0	65.1	66.1	67.2
28....	58.5	59.6	60.7	61.8	62.8	63.9	64.9	66.0	67.1
29....	58.4	59.5	60.5	61.6	62.6	63.7	64.8	65.8	66.9
30....	58.3	59.4	60.4	61.5	62.5	63.6	64.7	65.7	66.8
31....	58.2	59.3	60.3	61.4	62.4	63.5	64.5	65.6	66.6
32....	58.1	59.2	60.2	61.3	62.3	63.4	64.4	65.5	66.5
33....	58.0	59.0	60.1	61.2	62.2	63.2	64.3	65.4	66.4
34....	57.8	58.9	59.9	61.0	62.0	63.1	64.2	65.2	66.3
35....	57.7	58.8	59.8	60.9	61.9	63.0	64.0	65.1	66.1
36....	57.6	58.7	59.7	60.8	61.8	62.9	63.9	65.0	66.0
37....	57.5	58.6	59.6	60.7	61.7	62.8	63.8	64.8	65.9
38....	57.4	58.4	59.5	60.5	61.6	62.6	63.6	64.7	65.7
39....	57.3	58.3	59.4	60.4	61.5	62.5	63.5	64.6	65.6
40....	57.2	58.2	59.2	60.3	61.3	62.4	63.4	64.4	65.5
41....	57.1	58.1	59.1	60.2	61.2	62.3	63.3	64.3	65.4
42....	56.9	58.0	59.0	60.1	61.1	62.1	63.2	64.2	65.2
43....	56.8	57.9	58.9	59.9	61.0	62.0	63.1	64.1	65.1
44....	56.7	57.8	58.8	59.8	60.9	61.9	62.9	64.0	65.0
45....	56.6	57.6	58.7	59.7	60.7	61.8	62.8	63.8	64.9
46....	56.5	57.5	58.6	59.6	60.6	61.6	62.6	63.7	64.7
47....	56.4	57.4	58.4	59.5	60.5	61.5	62.5	63.6	64.6
48....	56.3	57.3	58.3	59.3	60.4	61.4	62.4	63.4	64.5
49....	56.2	57.2	58.2	59.2	60.3	61.3	62.3	63.3	64.3

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.								
	55	56	57	58	59	60	61	62	63
	Corresponding degrees A. P. I. at 60° F.								
50....	56.1	57.1	58.1	59.1	60.2	61.2	62.2	63.2	64.2
51....	56.0	57.0	58.0	59.0	60.1	61.1	62.1	63.1	64.1
52....	55.9	56.9	57.9	58.9	59.9	60.9	61.9	62.9	64.0
53....	55.7	56.7	57.8	58.8	59.8	60.8	61.8	62.8	63.9
54....	55.6	56.6	57.6	58.6	59.7	60.7	61.7	62.7	63.7
55....	55.5	56.5	57.5	58.5	59.6	60.6	61.6	62.6	63.6
56....	55.4	56.4	57.4	58.4	59.4	60.4	61.4	62.5	63.5
57....	55.3	56.3	57.3	58.3	59.3	60.3	61.3	62.4	63.4
58....	55.2	56.2	57.2	58.2	59.2	60.2	61.2	62.3	63.3
59....	55.1	56.1	57.1	58.1	59.1	60.1	61.1	62.1	63.1
60....	55.0	56.0	57.0	58.0	59.0	60.0	61.0	62.0	63.0
61....	54.9	55.9	56.9	57.9	58.9	59.9	60.9	61.9	62.9
62....	54.8	55.8	56.8	57.8	58.8	59.8	60.8	61.8	62.8
63....	54.7	55.7	56.6	57.6	58.6	59.6	60.6	61.6	62.6
64....	54.6	55.6	56.5	57.5	58.5	59.5	60.5	61.5	62.5
65....	54.5	55.4	56.4	57.4	58.4	59.4	60.4	61.4	62.4
66....	54.4	55.3	56.3	57.3	58.3	59.3	60.3	61.3	62.3
67....	54.3	55.2	56.2	57.2	58.2	59.2	60.2	61.2	62.2
68....	54.2	55.1	56.1	57.1	58.1	59.1	60.1	61.0	62.0
69....	54.1	55.0	56.0	57.0	58.0	59.0	60.0	60.9	61.9
70....	54.0	54.9	55.9	56.9	57.9	58.9	59.8	60.8	61.8
71....	53.9	54.8	55.8	56.8	57.8	58.7	59.7	60.7	61.7
72....	53.8	54.7	55.7	56.7	57.7	58.6	59.6	60.6	61.6
73....	53.7	54.6	55.6	56.6	57.6	58.5	59.5	60.4	61.4
74....	53.6	54.5	55.5	56.5	57.4	58.4	59.4	60.3	61.3
75....	53.5	54.4	55.4	56.4	57.3	58.3	59.3	60.2	61.2
76....	53.4	54.3	55.3	56.3	57.2	58.2	59.2	60.1	61.1
77....	53.3	54.2	55.2	56.1	57.1	58.1	59.0	60.0	61.0
78....	53.2	54.1	55.1	56.0	57.0	58.0	58.9	59.9	60.9
79....	53.1	54.0	55.0	55.9	56.9	57.9	58.8	59.8	60.8
80....	53.0	53.9	54.9	55.8	56.8	57.8	58.7	59.7	60.6
81....	52.9	53.8	54.8	55.7	56.7	57.6	58.6	59.6	60.5
82....	52.8	53.7	54.7	55.6	56.6	57.5	58.5	59.4	60.4
83....	52.7	53.6	54.6	55.5	56.5	57.4	58.4	59.3	60.3
84....	52.6	53.5	54.5	55.4	56.4	57.3	58.3	59.2	60.2
85....	52.5	53.4	54.4	55.3	56.3	57.2	58.1	59.1	60.0
86....	52.4	53.3	54.2	55.2	56.1	57.1	58.0	59.0	59.9
87....	52.3	53.2	54.1	55.1	56.0	57.0	57.9	58.9	59.8
88....	52.2	53.1	54.0	55.0	55.9	56.9	57.8	58.7	59.7
89....	52.1	53.0	53.9	54.9	55.8	56.8	57.7	58.6	59.6
90....	52.0	52.9	53.8	54.8	55.7	56.7	57.6	58.5	59.5
91....	51.9	52.8	53.7	54.7	55.6	56.6	57.5	58.4	59.4
92....	51.8	52.7	53.6	54.6	55.5	56.5	57.4	58.3	59.2
93....	51.7	52.6	53.5	54.5	55.4	56.4	57.3	58.2	59.1
94....	51.6	52.5	53.4	54.4	55.3	56.2	57.2	58.1	59.0
95....	51.5	52.4	53.3	54.3	55.2	56.1	57.0	58.0	58.9
96....	51.4	52.3	53.2	54.2	55.1	56.0	56.9	57.8	58.8
97....	51.3	52.2	53.1	54.1	55.0	55.9	56.8	57.7	58.7
98....	51.2	52.1	53.0	54.0	54.9	55.8	56.7	57.6	58.6
99....	51.1	52.0	52.9	53.9	54.8	55.7	56.6	57.5	58.5

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.								
	55	56	57	58	59	60	61	62	63
	Corresponding degrees A. P. I. at 60° F.								
100....	51.0	51.9	52.8	53.8	54.7	55.6	56.5	57.4	58.4
101....	50.9	51.8	52.7	53.7	54.6	55.5	56.4	57.3	58.3
102....	50.8	51.7	52.6	53.6	54.5	55.4	56.3	57.2	58.2
103....	50.7	51.6	52.5	53.5	54.4	55.3	56.2	57.1	58.0
104....	50.6	51.5	52.4	53.4	54.3	55.2	56.1	57.0	57.9
105....	50.5	51.4	52.3	53.3	54.2	55.1	56.0	56.9	57.8
106....	50.4	51.3	52.2	53.2	54.1	55.0	55.9	56.8	57.7
107....	50.4	51.3	52.2	53.1	54.0	54.9	55.8	56.7	57.6
108....	50.3	51.2	52.1	53.0	53.9	54.8	55.7	56.6	57.5
109....	50.2	51.1	52.0	52.9	53.8	54.7	55.6	56.5	57.4
110....	50.1	51.0	51.9	52.8	53.7	54.6	55.5	56.4	57.3
111....	50.0	50.9	51.8	52.7	53.6	54.5	55.4	56.3	57.2
112....	49.9	50.8	51.7	52.6	53.5	54.4	55.3	56.2	57.1
113....	49.8	50.7	51.6	52.5	53.4	54.3	55.2	56.1	57.0
114....	49.7	50.6	51.5	52.4	53.3	54.2	55.1	56.0	56.9
115....	49.6	50.5	51.4	52.3	53.2	54.1	55.0	55.8	56.7
116....	49.5	50.4	51.3	52.2	53.1	54.0	54.9	55.7	56.6
117....	49.4	50.3	51.2	52.1	53.0	53.9	54.8	55.6	56.5
118....	49.4	50.2	51.1	52.0	52.9	53.8	54.7	55.5	56.4
119....	49.3	50.1	51.0	51.9	52.8	53.7	54.6	55.4	56.3
120....	49.2	50.0	50.9	51.8	52.7	53.6	54.5	55.3	56.2
121....	49.1	50.0	50.8	51.7	52.6	53.5	54.4	55.2	56.1
122....	49.0	49.9	50.8	51.6	52.5	53.4	54.3	55.1	56.0
123....	48.9	49.8	50.7	51.6	52.4	53.3	54.2	55.0	55.9
124....	48.8	49.7	50.6	51.5	52.3	53.2	54.1	54.9	55.8
125....	48.7	49.6	50.5	51.4	52.2	53.1	54.0	54.8	55.7

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.								
	64	65	66	67	68	69	70	71	72
	Corresponding degrees A. P. I. at 60° F.								
0....	72.0	73.2	74.3	75.5	76.6	77.7	78.8	80.0	81.2
1....	71.9	73.0	74.1	75.3	76.4	77.6	78.7	79.8	81.0
2....	71.7	72.9	74.0	75.2	76.3	77.4	78.5	79.7	80.9
3....	71.6	72.7	73.8	75.0	76.1	77.3	78.4	79.5	80.7
4....	71.5	72.6	73.7	74.9	76.0	77.1	78.2	79.3	80.5
5....	71.3	72.4	73.5	74.7	75.8	77.0	78.1	79.2	80.4
6....	71.2	72.3	73.4	74.6	75.7	76.8	77.9	79.0	80.2
7....	71.0	72.2	73.3	74.4	75.5	76.6	77.8	78.9	80.0
8....	70.9	72.0	73.1	74.3	75.4	76.5	77.6	78.7	79.9
9....	70.8	71.9	73.0	74.1	75.2	76.3	77.4	78.5	79.7
10....	70.6	71.7	72.8	74.0	75.1	76.2	77.3	78.4	79.5
11....	70.5	71.6	72.7	73.8	74.9	76.0	77.1	78.2	79.4
12....	70.3	71.4	72.5	73.7	74.8	75.9	77.0	78.1	79.2
13....	70.2	71.3	72.4	73.5	74.6	75.7	76.8	77.9	79.1
14....	70.1	71.2	72.3	73.4	74.5	75.6	76.7	77.8	78.9
15....	69.9	71.0	72.1	73.2	74.3	75.4	76.5	77.6	78.7
16....	69.8	70.9	72.0	73.1	74.2	75.3	76.4	77.5	78.6
17....	69.7	70.8	71.8	72.9	74.0	75.1	76.2	77.3	78.4
18....	69.5	70.6	71.7	72.8	73.9	75.0	76.1	77.2	78.3
19....	69.4	70.5	71.5	72.6	73.7	74.8	75.9	77.0	78.1
20....	69.2	70.3	71.4	72.5	73.6	74.7	75.8	76.9	78.0
21....	69.1	70.2	71.3	72.4	73.4	74.5	75.6	76.7	77.8
22....	69.0	70.0	71.1	72.2	73.3	74.4	75.5	76.5	77.6
23....	68.8	69.9	71.0	72.1	73.1	74.2	75.3	76.4	77.5
24....	68.7	69.8	70.8	71.9	73.0	74.1	75.1	76.2	77.3
25....	68.5	69.6	70.7	71.8	72.8	73.9	75.0	76.1	77.2
26....	68.4	69.5	70.6	71.6	72.7	73.8	74.9	75.9	77.0
27....	68.3	69.4	70.4	71.5	72.5	73.6	74.7	75.8	76.9
28....	68.1	69.2	70.3	71.3	72.4	73.5	74.6	75.6	76.7
29....	68.0	69.1	70.1	71.2	72.2	73.3	74.4	75.5	76.6
30....	67.9	68.9	70.0	71.0	72.1	73.2	74.3	75.3	76.4
31....	67.7	68.8	69.8	70.9	72.0	73.0	74.1	75.2	76.3
32....	67.6	68.7	69.7	70.8	71.8	72.9	74.0	75.0	76.1
33....	67.5	68.5	69.6	70.6	71.7	72.8	73.8	74.9	76.0
34....	67.3	68.4	69.4	70.5	71.5	72.6	73.7	74.7	75.8
35....	67.2	68.2	69.3	70.3	71.4	72.4	73.5	74.6	75.6
36....	67.0	68.1	69.1	70.2	71.2	72.3	73.4	74.4	75.5
37....	66.9	68.0	69.0	70.1	71.1	72.2	73.2	74.3	75.3
38....	66.8	67.8	68.9	69.9	71.0	72.0	73.1	74.1	75.2
39....	66.7	67.7	68.7	69.8	70.8	71.9	72.9	74.0	75.0
40....	66.5	67.6	68.6	69.7	70.7	71.8	72.8	73.8	74.9
41....	66.4	67.5	68.5	69.6	70.6	71.6	72.7	73.7	74.8
42....	66.3	67.3	68.3	69.4	70.4	71.5	72.5	73.5	74.6
43....	66.2	67.2	68.2	69.3	70.3	71.3	72.4	73.4	74.5
44....	66.0	67.1	68.1	69.2	70.2	71.2	72.2	73.2	74.3
45....	65.9	66.9	67.9	69.0	70.0	71.0	72.1	73.1	74.2
46....	65.7	66.8	67.8	68.9	69.9	70.9	71.9	72.9	74.0
47....	65.6	66.6	67.7	68.7	69.7	70.8	71.8	72.8	73.9
48....	65.5	66.5	67.5	68.6	69.6	70.6	71.7	72.7	73.7
49....	65.4	66.4	67.4	68.4	69.4	70.5	71.5	72.5	73.6

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.								
	64	65	66	67	68	69	70	71	72
	Corresponding degrees A. P. I. at 60° F.								
50....	65.3	66.3	67.3	68.3	69.3	70.4	71.4	72.4	73.4
51....	65.1	66.2	67.2	68.2	69.2	70.2	71.2	72.2	73.3
52....	65.0	66.0	67.0	68.0	69.0	70.1	71.1	72.1	73.2
53....	64.9	65.9	66.9	67.9	68.9	70.0	71.0	72.0	73.0
54....	64.8	65.8	66.8	67.8	68.8	69.8	70.8	71.8	72.9
55....	64.6	65.6	66.6	67.7	68.7	69.7	70.7	71.7	72.7
56....	64.5	65.5	66.5	67.5	68.5	69.5	70.5	71.5	72.6
57....	64.4	65.4	66.4	67.4	68.4	69.4	70.4	71.4	72.4
58....	64.3	65.3	66.3	67.3	68.3	69.3	70.3	71.3	72.3
59....	64.1	65.1	66.1	67.1	68.1	69.1	70.1	71.1	72.2
60....	64.0	65.0	66.0	67.0	68.0	69.0	70.0	71.0	72.0
61....	63.9	64.9	65.9	66.9	67.9	68.9	69.9	70.9	71.9
62....	63.8	64.8	65.8	66.8	67.8	68.8	69.8	70.8	71.8
63....	63.6	64.6	65.6	66.6	67.6	68.6	69.6	70.6	71.6
64....	63.5	64.5	65.5	66.5	67.5	68.5	69.5	70.5	71.5
65....	63.4	64.4	65.4	66.4	67.3	68.3	69.3	70.3	71.3
66....	63.2	64.2	65.2	66.2	67.2	68.2	69.2	70.2	71.2
67....	63.1	64.1	65.1	66.1	67.1	68.1	69.1	70.1	71.1
68....	63.0	64.0	65.0	66.0	67.0	68.0	68.9	69.9	70.9
69....	62.9	63.9	64.9	65.9	66.8	67.8	68.8	69.8	70.8
70....	62.8	63.8	64.7	65.7	66.7	67.7	68.6	69.6	70.6
71....	62.6	63.6	64.6	65.6	66.6	67.6	68.5	69.5	70.5
72....	62.5	63.5	64.5	65.4	66.4	67.4	68.4	69.4	70.4
73....	62.4	63.4	64.3	65.3	66.3	67.3	68.3	69.3	70.3
74....	62.3	63.2	64.2	65.2	66.2	67.2	68.1	69.1	70.1
75....	62.2	63.1	64.1	65.1	66.0	67.0	68.0	69.0	70.0
76....	62.0	63.0	64.0	65.0	65.9	66.9	67.9	68.8	69.8
77....	61.9	62.9	63.9	64.8	65.8	66.8	67.7	68.7	69.7
78....	61.8	62.8	63.7	64.7	65.7	66.6	67.6	68.6	69.6
79....	61.7	62.7	63.6	64.6	65.6	66.5	67.5	68.4	69.4
80....	61.6	62.6	63.5	64.5	65.4	66.4	67.4	68.3	69.3
81....	61.5	62.4	63.4	64.4	65.3	66.3	67.2	68.2	69.1
82....	61.4	62.3	63.3	64.2	65.2	66.2	67.1	68.1	69.0
83....	61.2	62.2	63.1	64.1	65.1	66.0	67.0	67.9	68.9
84....	61.1	62.1	63.0	64.0	64.9	65.9	66.8	67.8	68.7
85....	61.0	61.9	62.9	63.9	64.8	65.8	66.7	67.6	68.6
86....	60.9	61.8	62.8	63.7	64.7	65.6	66.6	67.5	68.5
87....	60.8	61.7	62.6	63.6	64.5	65.5	66.4	67.4	68.4
88....	60.6	61.6	62.5	63.5	64.4	65.4	66.3	67.2	68.2
89....	60.5	61.5	62.4	63.4	64.3	65.2	66.2	67.1	68.1
90....	60.4	61.4	62.3	63.2	64.2	65.1	66.1	67.0	68.0
91....	60.3	61.2	62.2	63.1	64.0	65.0			
92....	60.2	61.1	62.0	63.0	63.9	64.9			
93....	60.1	61.0	61.9	62.9	63.8	64.8			
94....	59.9	60.9	61.8	62.8	63.7	64.6			
95....	59.8	60.8	61.7	62.6	63.5	64.5			
96....	59.7	60.6	61.6	62.5	63.4	64.4			
97....	59.6	60.5	61.4	62.4	63.3	64.2			
98....	59.5	60.4	61.3	62.3	63.2	64.1			
99....	59.4	60.3	61.2	62.1	63.0	64.0			

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.					
	64	65	66	67	68	69
	Corresponding degrees A. P. I. at 60° F.					
100....	59.3	60.2	61.1	62.0	62.9	63.9
101....	59.2	60.1	61.0	61.9	62.8	63.8
102....	59.1	60.0	60.9	61.8	62.7	63.6
103....	58.9	59.8	60.8	61.7	62.6	63.5
104....	58.8	59.7	60.6	61.6	62.5	63.4
105....	58.7	59.6	60.5	61.5	62.4	63.3
106....	58.6	59.5	60.4	61.3	62.2	63.2
107....	58.5	59.4	60.3	61.2	62.1	63.0
108....	58.4	59.3	60.2	61.1	62.0	62.9
109....	58.3	59.2	60.1	61.0	61.9	62.8
110....	58.2	59.1	60.0	60.9	61.8	62.7
111....	58.1	59.0	59.9	60.8	61.7	62.6
112....	58.0	58.8	59.7	60.6	61.5	62.5
113....	57.8	58.7	59.6	60.5	61.4	62.3
114....	57.7	58.6	59.5	60.4	61.3	62.2
115....	57.6	58.5	59.4	60.3	61.2	62.1
116....	57.5	58.4	59.3	60.2	61.1	62.0
117....	57.4	58.3	59.2	60.1	61.0	61.9
118....	57.3	58.2	59.1	60.0	60.9	61.8
119....	57.2	58.1	59.0	59.9	60.8	61.7
120....	57.1	58.0	58.9	59.8	60.6	61.5
121....	57.0	57.9	58.7	59.6	60.5	61.4
122....	56.9	57.8	58.6	59.5	60.4	61.3
123....	56.8	57.7	58.5	59.4	60.3	61.2
124....	56.7	57.6	58.4	59.3	60.2	61.1
125....	56.6	57.5	58.3	59.2	60.1	61.0

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I								
	73	74	75	76	77	78	79	80	81
	Corresponding degrees A. P. I. at 60° F.								
0....	82.3	83.4	84.6	85.7	86.9	88.1	89.2	90.4	91.6
1....	82.1	83.3	84.4	85.6	86.7	87.9	89.0	90.2	91.4
2....	82.0	83.1	84.3	85.4	86.5	87.7	88.8	90.0	91.2
3....	81.8	82.9	84.1	85.2	86.3	87.5	88.7	89.8	91.0
4....	81.6	82.7	83.9	85.0	86.2	87.3	88.5	89.6	90.8
5....	81.5	82.6	83.7	84.9	86.0	87.2	88.3	89.4	90.6
6....	81.3	82.4	83.6	84.7	85.8	87.0	88.1	89.3	90.4
7....	81.1	82.2	83.4	84.5	85.7	86.8	88.0	89.1	90.2
8....	81.0	82.1	83.2	84.4	85.5	86.7	87.8	88.9	90.0
9....	80.8	81.9	83.1	84.2	85.3	86.5	87.6	88.7	89.8
10....	80.6	81.7	82.9	84.0	85.1	86.3	87.4	88.6	89.7
11....	80.5	81.6	82.7	83.8	85.0	86.1	87.2	88.4	89.5
12....	80.3	81.4	82.5	83.6	84.8	85.9	87.0	88.2	89.3
13....	80.1	81.2	82.4	83.5	84.6	85.7	86.9	88.0	89.1
14....	80.0	81.1	82.2	83.3	84.4	85.6	86.7	87.8	88.9
15....	79.8	80.9	82.0	83.1	84.2	85.4	86.5	87.6	88.7
16....	79.7	80.8	81.9	83.0	84.1	85.2	86.3	87.5	88.6
17....	79.5	80.6	81.7	82.8	83.9	85.0	86.1	87.3	88.4
18....	79.4	80.4	81.5	82.6	83.7	84.9	86.0	87.1	88.2
19....	79.2	80.3	81.4	82.5	83.6	84.7	85.8	86.9	88.0
20....	79.0	80.1	81.2	82.3	83.4	84.5	85.6	86.7	87.8
21....	78.9	79.9	81.0	82.1	83.2	84.3	85.4	86.5	87.6
22....	78.7	79.8	80.9	82.0	83.0	84.1	85.2	86.4	87.5
23....	78.6	79.6	80.7	81.8	82.9	84.0	85.1	86.2	87.3
24....	78.4	79.4	80.5	81.6	82.7	83.8	84.9	86.0	87.1
25....	78.2	79.3	80.4	81.5	82.5	83.6	84.7	85.8	86.9
26....	78.1	79.1	80.2	81.3	82.4	83.5	84.6	85.6	86.7
27....	77.9	79.0	80.1	81.2	82.2	83.3	84.4	85.4	86.5
28....	77.8	78.8	79.9	81.0	82.1	83.2	84.2	85.3	86.4
29....	77.6	78.7	79.8	80.8	81.9	83.0	84.1	85.1	86.2
30....	77.5	78.5	79.6	80.7	81.7	82.8	83.9	84.9	86.0
31....	77.3	78.4	79.4	80.5	81.6	82.7	83.7	84.8	85.8
32....	77.2	78.2	79.3	80.4	81.4	82.5	83.6	84.6	85.7
33....	77.0	78.1	79.1	80.2	81.2	82.3	83.4	84.4	85.5
34....	76.9	77.9	79.0	80.0	81.1	82.2	83.2	84.2	85.3
35....	76.7	77.7	78.8	79.8	80.9	82.0	83.0	84.1	85.1
36....	76.5	77.6	78.6	79.7	80.7	81.8	82.9	83.9	85.0
37....	76.4	77.4	78.5	79.5	80.6	81.6	82.7	83.7	84.8
38....	76.2	77.3	78.3	79.4	80.4	81.5	82.5	83.6	84.6
39....	76.1	77.1	78.2	79.2	80.3	81.3	82.4	83.4	84.5
40....	75.9	77.0	78.0	79.1	80.1	81.2	82.2	83.2	84.3
41....	75.8	76.8	77.9	78.9	79.9	81.0	82.0	83.1	84.1
42....	75.6	76.7	77.7	78.8	79.8	80.8	81.9	82.9	83.9
43....	75.5	76.5	77.6	78.6	79.6	80.7	81.7	82.7	83.8
44....	75.3	76.3	77.4	78.4	79.4	80.5	81.5	82.6	83.6
45....	75.2	76.2	77.2	78.3	79.3	80.3	81.4	82.4	83.4
46....	75.0	76.0	77.1	78.1	79.1	80.2	81.2	82.2	83.2
47....	74.9	75.9	76.9	78.0	79.0	80.0	81.1	82.1	83.1
48....	74.7	75.7	76.8	77.8	78.8	79.8	80.9	81.9	82.9
49....	74.6	75.6	76.6	77.7	78.7	79.7	80.7	81.8	82.8

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.								
	73	74	75	76	77	78	79	80	81
	Corresponding degrees A. P. I. at 60° F.								
50....	74.5	75.5	76.5	77.5	78.5	79.6	80.6	81.6	82.6
51....	74.3	75.3	76.3	77.4	78.4	79.4	80.4	81.4	82.4
52....	74.2	75.2	76.2	77.2	78.2	79.3	80.3	81.3	82.3
53....	74.0	75.0	76.0	77.1	78.1	79.1	80.1	81.1	82.1
54....	73.9	74.9	75.9	76.9	77.9	78.9	80.0	81.0	82.0
55....	73.7	74.7	75.7	76.8	77.8	78.8	79.8	80.8	81.8
56....	73.6	74.6	75.6	76.6	77.6	78.6	79.6	80.6	81.6
57....	73.4	74.4	75.4	76.5	77.5	78.5	79.5	80.5	81.5
58....	73.3	74.3	75.3	76.3	77.3	78.3	79.3	80.3	81.3
59....	73.2	74.2	75.2	76.2	77.2	78.2	79.2	80.2	81.2
60....	73.0	74.0	75.0	76.0	77.0	78.0	79.0	80.0	81.0
61....	72.9	73.9	74.9	75.9	76.8	77.8	78.8	79.8	80.8
62....	72.7	73.7	74.7	75.7	76.7	77.7	78.7	79.7	80.7
63....	72.6	73.6	74.6	75.6	76.5	77.5	78.5	79.5	80.5
64....	72.4	73.4	74.4	75.4	76.4	77.4	78.4	79.4	80.4
65....	72.3	73.3	74.3	75.2	76.2	77.2	78.2	79.2	80.2
66....	72.2	73.1	74.1	75.1	76.1	77.1	78.1	79.1	80.0
67....	72.0	73.0	74.0	75.0	75.9	76.9	77.9	78.9	79.9
68....	71.9	72.9	73.9	74.8	75.8	76.8	77.8	78.8	79.7
69....	71.7	72.7	73.7	74.7	75.6	76.6	77.6	78.6	79.6
70....	71.6	72.6	73.6	74.5	75.5	76.5	77.5	78.4	79.4
71....	71.4	72.4	73.4	74.4	75.3	76.3	77.3	78.3	79 3
72....	71.3	72.3	73.3	74.2	75.2	76.2	77.1	78.1	79.1
73....	71.2	72.2	73.1	74.1	75.0	76.0	77.0	78.0	78.9
74....	71.0	72.0	73.0	73.9	74.9	75.9	76.8	77.8	78.8
75....	70.9	71.9	72.9	73.8	74.8	75.8	76.7	77.7	78.7
76....	70.8	71.7	72.7	73.7	74.6	75.6	76.6	77.5	78.5
77....	70.6	71.6	72.6	73.5	74.5	75.5	76.4	77.4	78.4
78....	70.5	71.5	72.4	73.4	74.4	75.3	76.3	77.2	78.2
79....	70.4	71.3	72.3	73.2	74.2	75.2	76.1	77.1	78.0
80....	70.2	71.2	72.2	73.1	74.1	75.0	76.0	76.9	77.8
81....	70.1	71.0	72.0	73.0	73.9	74.9	75.8	76.8	77.7
82....	70.0	70.9	71.9	72.8	73.8	74.7	75.6	76.6	77.5
83....	69.8	70.8	71.7	72.6	73.6	74.6	75.5	76.5	77.4
84....	69.7	70.6	71.6	72.5	73.4	74.4	75.3	76.3	77.2
85....	69.5	70.5	71.4	72.4	73.3	74.3	75.2	76.2	77.1
86....	69.4	70.4	71.3	72.2	73.2	74.1	75.1	76.0	77.0
87....	69.3	70.2	71.2	72.1	73.0	74.0	74.9	75.9	76.8
88....	69.1	70.1	71.0	72.0	72.9	73.8	74.8	75.7	76.6
89....	69.0	70.0	70.9	71.8	72.8	73.7	74.6	75.6	76.5
90....	68.9	69.8	70.8	71.7	72.6	73.6	74.5	75.5	76.4

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.								
	82	83	84	85	86	87	88	89	90
	Corresponding degrees A. P. I. at 60° F.								
0....	92.7	93.9	95.1	96.3	97.5	98.7	99.9	101.1	102.3
1....	92.5	93.7	94.9	96.1	97.3	98.5	99.7	100.9	102.1
2....	92.4	93.5	94.7	95.9	97.1	98.3	99.5	100.7	101.9
3....	92.2	93.3	94.5	95.7	96.9	98.1	99.3	100.4	101.6
4....	92.0	93.1	94.3	95.5	96.7	97.9	99.1	100.2	101.4
5....	91.8	92.9	94.1	95.3	96.5	97.7	98.9	100.0	101.2
6....	91.6	92.7	93.9	95.1	96.3	97.5	98.7	99.8	101.0
7....	91.4	92.5	93.7	94.9	96.0	97.2	98.4	99.6	100.7
8....	91.2	92.4	93.5	94.7	95.8	97.0	98.2	99.3	100.5
9....	91.0	92.2	93.3	94.5	95.6	96.8	98.0	99.1	100.3
10....	90.8	92.0	93.1	94.2	95.4	96.6	97.8	98.9	100.0
11....	90.6	91.8	92.9	94.0	95.2	96.4	97.5	98.7	99.8
12....	90.4	91.6	92.7	93.8	95.0	96.1	97.3	98.4	99.6
13....	90.2	91.4	92.5	93.6	94.8	95.9	97.1	98.2	99.4
14....	90.0	91.2	92.3	93.4	94.6	95.7	96.9	98.0	99.2
15....	89.9	91.0	92.1	93.2	94.4	95.5	96.7	97.8	99.0
16....	89.7	90.8	91.9	93.0	94.2	95.3	96.5	97.6	98.7
17....	89.5	90.6	91.7	92.8	94.0	95.1	96.3	97.4	98.5
18....	89.3	90.4	91.5	92.6	93.8	94.9	96.1	97.2	98.3
19....	89.1	90.2	91.3	92.4	93.6	94.7	95.9	97.0	98.1
20....	88.9	90.0	91.1	92.2	93.4	94.5	95.7	96.8	97.9
21....	88.7	89.8	90.9	92.0	93.2	94.3	95.4	96.5	97.7
22....	88.6	89.7	90.8	91.9	93.0	94.1	95.2	96.3	97.5
23....	88.4	89.5	90.6	91.7	92.8	93.9	95.0	96.1	97.2
24....	88.2	89.3	90.4	91.5	92.6	93.7	94.8	95.9	97.0
25....	88.0	89.1	90.2	91.3	92.4	93.5	94.6	95.7	96.8
26....	87.8	88.9	90.0	91.1	92.2	93.3	94.4	95.5	96.6
27....	87.6	88.7	89.8	90.9	92.0	93.1	94.2	95.3	96.4
28....	87.4	88.5	89.6	90.7	91.8	92.9	94.0	95.1	96.2
29....	87.3	88.4	89.4	90.5	91.6	92.7	93.8	94.9	96.0
30....	87.1	88.2	89.3	90.3	91.4	92.5	93.6	94.7	95.8
31....	86.9	88.0	89.1	90.2	91.2	92.3	93.4	94.5	95.6
32....	86.7	87.8	88.9	90.0	91.0	92.1	93.2	94.3	95.4
33....	86.5	87.6	88.7	89.8	90.8	91.9	93.0	94.1	95.2
34....	86.4	87.4	88.5	89.6	90.7	91.7	92.8	93.9	95.0
35....	86.2	87.2	88.3	89.4	90.5	91.5	92.6	93.7	94.8
36....	86.0	87.1	88.2	89.2	90.3	91.3	92.4	93.5	94.6
37....	85.9	86.9	88.0	89.0	90.1	91.2	92.2	93.3	94.4
38....	85.7	86.7	87.8	88.8	89.9	91.0	92.1	93.1	94.2
39....	85.5	86.6	87.6	88.7	89.7	90.8	91.9	92.9	94.0
40....	85.4	86.4	87.5	88.5	89.6	90.6	91.7	92.7	93.8
41....	85.2	86.2	87.3	88.3	89.4	90.4	91.5	92.5	93.6
42....	85.0	86.0	87.1	88.1	89.2	90.2	91.3	92.4	93.4
43....	84.8	85.9	86.9	88.0	89.0	90.0	91.1	92.2	93.2
44....	84.7	85.7	86.7	87.8	88.8	89.9	90.9	92.0	93.0
45....	84.5	85.5	86.6	87.6	88.6	89.7	90.7	91.8	92.8
46....	84.3	85.3	86.4	87.4	88.4	89.5	90.5	91.6	92.6
47....	84.1	85.2	86.2	87.2	88.3	89.3	90.4	91.4	92.4
48....	84.0	85.0	86.0	87.1	88.1	89.1	90.2	91.2	92.2
49....	83.8	84.8	85.9	86.9	87.9	88.9	90.0	91.0	92.0

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.								
	82	83	84	85	86	87	88	89	90
	Corresponding degrees A. P. I. at 60° F.								
50....	83.6	84.7	85.7	86.7	87.7	88.8	89.8	90.8	91.9
51....	83.5	84.5	85.5	86.6	87.6	88.6	89.6	90.7	91.7
52....	83.3	84.3	85.4	86.4	87.4	88.4	89.4	90.5	91.5
53....	83.1	84.1	85.2	86.2	87.2	88.2	89.2	90.3	91.3
54....	83.0	84.0	85.0	86.0	87.0	88.0	89.1	90.1	91.1
55. ..	82.8	83.8	84.8	85.8	86.8	87.8	88.9	89.9	90.9
56....	82.6	83.6	84.7	85.7	86.7	87.7	88.7	89.7	90.7
57....	82.5	83.5	84.5	85.5	86.5	87.5	88.5	89.5	90.5
58....	82.3	83.3	84.3	85.3	86.3	87.3	88.3	89.3	90.3
59....	82.2	83.2	84.2	85.2	86.2	87.2	88.2	89.2	90.2
60....	82.0	83.0	84.0	85.0	86.0	87.0	88.0	89.0	90.0
61....	81.8	82.8	83.8	84.8	85.8	86.8	87.8	88.8	89.8
62....	81.7	82.7	83.7	84.7	85.7	86.7	87.7	88.7	89.7
63....	81.5	82.5	83.5	84.5	85.5	86.5	87.5	88.5	89.4
64....	81.3	82.3	83.3	84.3	85.3	86.3	87.3	88.3	89.3
65....	81.2	82.2	83.2	84.1	85.1	86.1	87.1	88.1	89.1
66....	81.0	82.0	83.0	84.0	85.0	86.0	87.0	87.9	88.9
67....	80.9	81.9	82.9	83.8	84.8	85.8	86.8	87.8	88.7
68....	80.7	81.7	82.7	83.6	84.6	85.6	86.6	87.6	88.6
69....	80.6	81.5	82.5	83.5	84.5	85.5	86.5	87.4	88.4
70....	80.4	81.4	82.4	83.3	84.3	85.3	86.3	87.2	88.2
71....	80.2	81.2	82.2	83.1	84.1	85.1	86.1	87.0	88.0
72....	80.1	81.1	82.0	83.0	84.0	84.9	85.9	86.9	87.8
73....	79.9	80.9	81.9	82.8	83.8	84.8	85.8	86.7	87.7
74....	79.8	80.7	81.7	82.7	83.6	84.6	85.6	86.5	87.5
75....	79.6	80.6	81.6	82.5	83.5	84.4	85.4	86.4	87.3
76....	79.4	80.4	81.4	82.3	83.3	84.3	85.2	86.2	87.2
77....	79.3	80.3	81.2	82.2	83.2	84.1	85.1	86.0	87.0
78....	79.1	80.1	81.1	82.0	83.0	83.9	84.9	85.8	86.8
79....	79.0	79.9	80.9	81.8	82.8	83.8	84.7	85.7	86.6
80....	78.8	79.8	80.7	81.7	82.6	83.6	84.6	85.5	86.5
81....	78.7	79.6	80.6	81.5	82.5	83.4	84.4	85.3	86.3
82....	78.5	79.4	80.4	81.3	82.3	83.2	84.2	85.1	86.1
83....	78.4	79.3	80.3	81.2	82.2	83.1	84.1	85.0	86.0
84....	78.2	79.1	80.1	81.0	82.0	82.9	83.9	84 8	85.8
85....	78.0	79.0	79.9	80.9	81.8	82.8	83.7	84.7	85.6
86....	77.9	78.8	79.8	80.7	81.7	82.6	83.6	84.5	85.4
87....	77.7	78.7	79.6	80.6	81.5	82.5	83.4	84.3	85.3
88....	77.6	78.5	79.5	80.4	81.3	82.3	83.2	84.2	85.1
89....	77.4	78.4	79.3	80.3	81.2	82.2	83.1	84.0	84.9
90....	77.3	78.2	79.2	80.1	81.0	82.0	82.9	83.8	84.8

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.								
	91	92	93	94	95	96	97	98	99
	Corresponding degrees A. P. I. at 60° F.								
0....	103.5	104.7	105.9	107.1	108.3	109.5	110.7	111.9	113.1
1....	103.3	104.5	105.7	106.8	108.0	109.3	110.5	111.7	112.8
2....	103.0	104.2	105.4	106.6	107.8	109.0	110.2	111.4	112.6
3....	102.8	104.0	105.2	106.4	107.6	108.8	110.0	111.2	112.3
4....	102.6	103.8	105.0	106.1	107.3	108.5	109.7	110.9	112.1
5....	102.3	103.5	104.7	105.9	107.1	108.3	109.5	110.6	111.8
6....	102.1	103.3	104.5	105.7	106.8	108.0	109.2	110.4	111.6
7....	101.9	103.1	104.2	105.4	106.6	107.8	109.0	110.1	111.3
8....	101.6	102.8	104.0	105.2	106.4	107.5	108.7	109.9	111.1
9....	101.4	102.6	103.8	104.9	106.1	107.3	108.4	109.6	110.8
10....	101.2	102.4	103.6	104.7	105.9	107.0	108.2	109.4	110.5
11....	101.0	102.2	103.3	104.4	105.7	106.8	108.0	109.1	110.3
12....	100.7	101.9	103.1	104.2	105.4	106.6	107.7	108.9	110.0
13....	100.5	101.7	102.8	104.0	105.2	106.3	107.5	108.6	109.8
14....	100.3	101.5	102.6	103.7	104.9	106.1	107.2	108.4	109.6
15....	100.1	101.3	102.4	103.5	104.7	105.8	107.0	108.1	109.3
16....	99.9	101.0	102.2	103.3	104.5	105.6	106.8	107.9	109.0
17....	99.6	100.8	101.9	102.0	104.2	105.4	106.5	107.6	108.8
18....	99.4	100.6	101.7	102.8	104.0	105.1	106.3	107.4	108.5
19....	99.2	100.4	101.5	102.6	103.7	104.8	106.0	107.1	108.2
20....	99.0	100.1	101.2	102.3	103.5	104.6	105.8	106.9	108.0
21....	98.8	99.9	101.0	102.1	103.3	104.4	105.5	106.6	107.8
22....	98.6	99.7	100.8	101.9	103.1	104.2	105.3	106.4	107.5
23....	98.3	99.5	100.6	101.7	102.8	103.9	105.1	106.2	107.3
24....	98.1	99.3	100.4	101.5	102.6	103.7	104.8	106.0	107.1
25....	97.9	99.1	100.2	101.3	102.4	103.5	104.6	105.7	106.8
26....	97.7	98.8	99.9	101.0	102.2	103.3	104.4	105.5	106.6
27....	97.5	98.6	99.7	100.8	101.9	103.0	104.1	105.2	106.4
28....	97.3	98.4	99.5	100.6	101.7	102.8	103.9	105.0	106.1
29....	97.1	98.2	99.3	100.4	101.5	102.6	103.7	104.8	105.9
30....	96.9	98.0	99.1	100.2	101.3	102.4	103.4	104.5	105.6
31....	96.7	97.8	98.8	99.9	101.0	102.1	103.2	104.3	105.4
32....	96.5	97.6	98.6	99.7	100.8	101.9	103.0	104 1	105.2
33....	96.3	97.4	98.4	99.5	100.6	101.7	102.8	103.9	105.0
34....	96.1	97.2	98.2	99.3	100.4	101.5	102.5	103.6	104.7
35....	95.9	97.0	98.0	99.1	100.2	101.3	102.3	103.4	104.5
36....	95.7	96.8	97.8	98.9	100.0	101.0	102.1	103.2	104.3
37....	95.5	96.6	97.6	98.7	99.8	100.8	101.9	103.0	104.1
38....	95.3	96.4	97.4	98.5	99.6	100.6	101.7	102.7	103.8
39....	95.1	96.1	97.2	98.2	99.3	100.4	101.4	102.5	103.6
40....	94.9	95.9	97.0	98.0	99.1	100.2	101.2	102.3	103.4
41....	94.7	95.7	96.8	97.8	98.9	99.9	101.0	102 0	103.1
42....	94.5	95.5	96.6	97.6	98.7	99.7	100.8	101.8	102.9
43....	94.3	95.3	96.4	97.4	98.5	99.5	100.6	101.6	102.7
44....	94.1	95.1	96.2	97.2	98.2	99.3	100.3	101.4	102.5
45....	93.9	94.9	95.9	97.0	98.0	99.1	100.1	101.2	102.2
46....	93.7	94.7	95.7	96.8	97.8	98.9	99.9	101.0	102.0
47....	93.5	94.5	95.5	96.6	97.6	98.7	99.7	100.7	101.8
48....	93.3	94.3	95.3	96.4	97.4	98.5	99.5	100.5	101.6
49....	93.1	94.1	95.1	96.2	97.2	98.2	99.3	100.3	101.3

Indicated Degrees A. P. I. at Various Temperatures, Corrected to Degrees A. P. I. at 60°F.—Continued

Observed temperature in °F.	Observed degrees A. P. I.								
	91	92	93	94	95	96	97	98	99
	Corresponding degrees A. P. I. at 60° F.								
50....	92.9	93.9	94.9	96.0	97.0	98.0	99.0	100.1	101.1
51....	92.7	93.7	94.8	95.8	96.8	97.8	98.8	99.9	100.9
52....	92.5	93.6	94.6	95.6	96.6	97.6	98.6	99.7	100.7
53....	92.3	93.4	94.4	95.4	96.4	97.4	98.4	99.5	100.5
54....	92.1	93.2	94.2	95.2	96.2	97.2	98.2	99.3	100.3
55. ..	91.9	93.0	94.0	95.0	96.0	97.0	98.0	99.0	100.1
56....	91.7	92.8	93.8	94.8	95.8	96.8	97.8	98.8	99.9
57....	91.5	92.6	93.6	94.6	95.6	96.6	97.6	98.6	99.6
58....	91.3	92.4	93.4	94.4	95.4	96.4	97.4	98.4	99.4
59....	91.2	92.2	93.2	94.2	95.2	96.2	97.2	98.2	99.2
60....	91.0	92.0	93.0	94.0	95.0	96.0	97.0	98.0	99.0
61....	90.8	91.8	92.8	93.8	94.8	95.8	96.8	97.8	98.8
62....	90.6	91.6	92.6	93.6	94.6	95.6	96.6	97.6	98.6
63....	90.4	91.4	92.4	93.4	94.4	95.4	96.4	97.4	98.4
64....	90.2	91.2	92.2	93.2	94.2	95.2	96.2	97.2	98.2
65....	90.0	91.0	92.0	93.0	94.0	95.0	96.0	97.0	98.0
66....	89.9	90.8	91.8	92.8	93.8	94.8	95.8	96.8	97.8
67....	89.7	90.7	91.6	92.6	93.6	94.6	95.6	96.6	97.5
68....	89.5	90.5	91.5	92.5	93.5	94.4	95.4	96.4	97.3
69....	89.4	90.3	91.3	92.3	93.3	94.2	95.2	96.2	97.1
70....	89.2	90.1	91.1	92.1	93.1	94.0	95.0	96.0	96.9
71....	89.0	89.9	90.9	91.9	92.9	93.8	94.8	95.8	96.7
72....	88.8	89.8	90.7	91.7	92.7	93.6	94.6	95.6	96.5
73....	88.6	89.6	90.6	91.5	92.5	93.4	94.4	95.4	96.3
74....	88.5	89.4	90.4	91.3	92.3	93.2	94.2	95.2	96.1
75....	88.3	89.2	90.2	91.2	92.1	93.1	94.0	95.0	96.0
76....	88.1	89.1	90.0	91.0	92.0	92.9	93.9	94.8	95.8
77....	87.9	88.9	89.8	90.8	91.8	92.7	93.7	94.6	95.6
78....	87.7	88.7	89.7	90.6	91.6	92.5	93.5	94.4	95.4
79....	87.6	88.5	89.5	90.4	91.4	92.3	93.3	94.2	95.2
80....	87.4	88.4	89.3	90.2	91.2	92.1	93.1	94.0	95.0
81....	87.2	88.2	89.1	90.1	91.0	91.9	92.9	93.8	94.8
82....	87.0	88.0	88.9	89.9	90.8	91.8	92.7	93.6	94.6
83....	86.9	87.8	88.8	89.7	90.7	91.6	92.5	93.4	94.4
84....	86.7	87.6	88.6	89.5	90.5	91.4	92.3	93.2	94.2
85....	86.5	87.5	88.4	89.4	90.3	91.2	92.2	93.1	94.0
86....	86.4	87.3	88.2	89.2	90.1	91.0	92.0	92.9	93.8
87....	86.2	87.1	88.0	89.0	89.9	90.8	91.8	92.7	93.6
88....	86.0	87.0	87.9	88.8	89.7	90.6	91.6	92.5	93.4
89....	85.9	86.8	87.7	88.6	89.6	90.5	91.4	92.3	93.2
90....	85.7	85.6	87.5	88.5	89.4	90.3	91.2	92.2	93.1

Abridged Volume Correction Table for Petroleum Oils*

This abridged table was prepared by the U. S. Bureau of Standards to meet a demand from the petroleum industry for a short and convenient table for reducing oil volumes to the basis of 60°F. (15.5°C.) It is based on the same data as Table 2, Bureau of Standards *Circular No. 154*. The Groups, Coefficients of Expansion, Degrees A. P. I. and Gravity Ranges of the abridged table are as follows:

Group Number	Coefficient of Expansion at 60° F.	Corresponding Degrees A. P. I.	Range of Group (degrees A. P. I. at 60° F.)
I	0.0004	22	Up to 34.9
II	0.0005	44	35 to 50.9
III	0.0006	58	51 to 63.9
IV	0.0007	72	64 to 78.9
V	0.0008	86	79 to 88.9
VI	0.00085	91	89 and higher

The table shows the volume occupied by 60°F. by a quantity of oil occupying a unit volume at the indicated temperatures. For example, if at 60°F. the A. P. I. gravity of the oil is 28 (Group 1), one gallon of this oil measured at 120°F. will have a volume of 0.9763 gal. at 60°F. The values given in the table are in the form of "multipliers"; that is, the volume of oil at the indicated temperature and degrees A. P. I. for each group, multiplied by the corresponding factor in the table, equals the volume at 60°F. For example, if the A. P. I. gravity of an oil at 60°F. equals 28 (Group 1) and the volume at 120°F. equals 6000 gal. then the volume at 60°F. equals 6000 x 0.9763, or 5857.8 gal.

*The table has been approved by the Bureau of Standards, Bureau of Mines, American Petroleum Institute and is American Society of Testing Materials Standard D 206-25.

This abridged table is intended to replace the various abridged tables and approximate correction factors heretofore employed in the oil industry. In case high accuracy is essential the complete table contained in Bureau of Standards *Circular No. 154* should be used, especially if large volumes or wide temperature ranges are involved.

Abridged Volume Correction Table for Petroleum Oils

Observed temperature in ° F.	Volume at 60° F. occupied by unit volume at indicated temperatures					
	Group I up to 34.9 degrees A.P.I. at 60° F.	Group II 35 to 50.9 degrees A.P.I. at 60° F.	Group III 51 to 63.9 degrees A.P.I. at 60° F.	Group IV 64 to 78.9 degrees A.P.I. at 60° F.	Group V 79 to 88.9 degrees A.P.I. at 60° F.	Group VI 89 and higher degrees A.P.I. at 60° F.
0	1.0242	1.0297	1.0361	1.0419	1.0476	1.0501
1	1.0238	1.0292	1.0355	1.0412	1.0468	1.0493
2	1.0234	1.0287	1.0349	1.0405	1.0460	1.0484
3	1.0230	1.0283	1.0343	1.0398	1.0453	1.0476
4	1.0226	1.0278	1.0337	1.0391	1.0445	1.0467
5	1.0222	1.0273	1.0331	1.0384	1.0437	1.0459
6	1.0218	1.0268	1.0325	1.0377	1.0429	1.0451
7	1.0214	1.0263	1.0319	1.0370	1.0421	1.0443
8	1.0210	1.0258	1.0313	1.0364	1.0414	1.0434
9	1.0206	1.0253	1.0307	1.0357	1.0406	1.0426
10	1,0202	1.0248	1,0301	1,0350	1.0398	1.0418
11	1.0198	1.0243	1.0295	1.0343	1.0390	1.0410
12	1.0194	1.0238	1.0289	1.0336	1.0382	1.0402
13	1.0189	1.0233	1.0283	1.0329	1.0375	1.0393
14	1.0185	1.0228	1.0277	1.0322	1.0367	1.0385
15	1.0181	1.0223	1.0271	1.0315	1.0359	1.0377
16	1.0177	1.0218	1.0265	1.0308	1.0351	1.0369
17	1.0173	1.0213	1.0259	1.0301	1.0343	1.0360
18	1.0169	1.0208	1.0253	1.0294	1.0335	1.0352
19	1.0165	1.0203	1.0247	1.0287	1.0327	1.0343
20	1.0161	1.0198	1.0241	1.0280	1.0319	1.0335
21	1.0157	1.0193	1.0235	1.0273	1.0311	1.0327
22	1.0153	1.0188	1.0229	1.0266	1.0303	1.0319
23	1.0148	1.0184	1.0223	1.0260	1.0296	1.0310
24	1.0144	1.0179	1.0217	1.0253	1.0288	1.0302
25	1.0140	1,0174	1.0211	1.0246	1.0280	1.0294
26	1.0136	1.0169	1.0205	1.0239	1.0272	1.0286
27	1.0132	1.0164	1.0199	1.0232	1.0264	1.0277
28	1.0128	1.0159	1.0193	1.0225	1.0256	1.0269
29	1.0124	1.0154	1.0187	1.0218	1.0248	1.0260
30	1.0120	1.0149	1.0181	1.0211	1.0240	1.0252
31	1.0116	1.0144	1.0175	1.0204	1.0232	1.0244
32	1.0112	1.0139	1.0169	1.0197	1.0224	1.0236
33	1.0108	1.0134	1.0163	1.0190	1.0216	1.0227
34	1.0104	1.0129	1.0157	1.0183	1.0208	1.0219
35	1.0100	1.0124	1.0151	1.0176	1.0200	1.0211
36	1.0096	1.0119	1.0145	1.0169	1.0192	1.0203
37	1.0092	1.0114	1.0139	1.0162	1.0184	1.0194
38	1.0088	1.0109	1.0133	1.0155	1.0176	1.0186
39	1.0084	1.0104	1.0127	1.0148	1.0168	1.0177
40	1.0080	1.0099	1.0121	1.0141	1.0160	1.0169
41	1.0076	1.0094	1.0115	1.0134	1.0152	1.0160
42	1.0072	1.0089	1.0109	1.0127	1.0144	1.0152
43	1.0068	1.0084	1.0103	1.0120	1.0136	1.0143
44	1.0064	1.0079	1.0097	1.0113	1.0128	1.0135

Abridged Volume Correction Table for Petroleum Oils—Continued

Observed temperature in ° F.	Volume at 60° F. occupied by unit volume at indicated temperatures					
	Group I up to 34.9 degrees A.P.I. at 60° F.	Group II 35 to 50.9 degrees A.P.I. at 60° F.	Group III 51 to 63.9 degrees A.P.I. at 60° F.	Group IV 64 to 78.9 degrees A.P.I. at 60° F.	Group V 79 to 88.9 degrees A.P.I. at 60° F.	Group VI 89 and higher degrees A.P.I. at 60° F.
45	1.0060	1.0074	1.0091	1.0106	1.0120	1.0126
46	1.0056	1.0069	1.0085	1.0099	1.0112	1.0118
47	1.0052	1.0064	1.0079	1.0092	1.0104	1.0110
48	1.0048	1.0059	1.0072	1.0084	1.0096	1.0101
49	1.0044	1.0054	1.0066	1.0077	1.0088	1.0093
50	1.0040	1.0049	1.0060	1.0070	1.0080	1.0084
51	1.0036	1.0044	1.0054	1.0063	1.0072	1.0076
52	1.0032	1.0039	1.0048	1.0056	1.0064	1.0067
53	1.0028	1.0035	1.0042	1.0049	1.0056	1.0059
54	1.0024	1.0030	1.0036	1.0042	1.0048	1.0050
55	1.0020	1.0025	1.0030	1.0035	1.0040	1.0042
56	1.0016	1.0020	1.0024	1.0028	1.0032	1.0034
57	1.0012	1.0015	1.0018	1.0021	1.0024	1.0025
58	1.0008	1.0010	1.0012	1.0014	1.0016	1.0017
59	1.0004	1.0005	1.0006	1.0007	1.0008	1.0008
60	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
61	.9996	.9995	.9994	.9993	.9992	.9992
62	.9992	.9990	.9988	.9986	.9984	.9983
63	.9988	.9985	.9982	.9979	.9976	.9975
64	.9984	.9980	.9976	.9972	.9968	.9966
65	9980	.9975	.9970	.9965	.9960	.9958
66	.9976	.9970	.9964	.9958	.9952	.9949
67	.9972	.9965	.9957	.9951	.9944	.9941
68	.9968	.9961	.9951	.9943	.9935	.9932
69	.9964	.9956	.9945	.9936	.9927	.9924
70	.9960	.9951	.9939	.9929	.9919	.9915
71	.9956	.9946	.9933	.9922	.9911	.9907
72	.9952	.9941	.9927	.9915	.9903	.9898
73	.9948	.9935	.9921	.9908	.9895	.9890
74	.9944	.9930	.9915	.9901	.9887	.9881
75	.9940	.9925	.9909	.9894	.9879	.9873
76	.9936	.9920	.9903	.9887	.9871	.9864
77	.9932	.9915	.9897	.9880	.9863	.9856
78	.9929	.9911	.9891	.9872	.9854	.9847
79	.9925	.9906	.9885	.9865	.9846	.9839
80	.9921	.9901	.9879	.9858	.9838	.9830
81	.9917	.9896	.9873	.9851	.9830	.9821
82	.9913	.9891	.9867	.9844	.9822	.9813
83	.9909	.9886	.9860	.9837	.9814	.9804
84	.9905	.9881	.9854	.9830	.9806	.9796
85	.9901	.9876	.9848	.9823	.9798	.9787
86	.9897	.9871	.9842	.9816	.9790	.9779
87	.9893	.9866	.9836	.9809	.9782	.9770
88	.9889	.9861	.9830	.9802	.9773	.9762
89	.9885	.9856	.9824	.9795	.9765	.9753
90	.9881	.9851	.9818	.9788	.9757	.9745

Abridged Volume Correction Table for Petroleum Oils—Continued

Observed temperature in °F.	Volume at 60° F. occupied by unit volume at indicated temperatures: Group I up to 34.9 degrees A. P. I. at 60° F.	Group II 35 to 50.9 degrees A. P. I. at 60° F.	Group III 51 to 63.9 degrees A. P. I. at 60° F.
91	0.9877	0.9846	0.9812
92	.9873	.9841	.9806
93	.9869	.9836	.9800
94	.9865	.9831	.9794
95	.9861	.9826	.9788
96	.9857	.9821	.9782
97	.9853	.9816	.9776
98	.9849	.9812	.9769
99	9845	.9807	.9763
100	.9841	.9802	.9757
101	.9837	.9797	.9751
102	.9833	.9792	.9745
103	.9830	.9786	9738
104	.9826	.9781	.9732
105	.9822	.9776	.9726
106	.9818	.9771	.9720
107	.9814	.9766	.9714
108	.9811	.9762	.9708
109	.9807	.9757	.9702
110	.9803	.9752	.9696
111	.9799	.9747	.9690
112	.9795	.9742	.9684
113	.9791	.9737	.9678
114	.9787	.9732	.9672
115	.9783	.9727	.9666
116	.9778	.9722	.9660
117	.9775	.9717	.9654
118	.9771	.9712	.9647
119	.9767	.9707	.9641
120	.9763	.9702	.9635
121	.9759	.9697	.9629
122	.9755	.9692	.9623
123	.9752	.9687	.9617
124	.9748	.9682	.9611
125	.9744	.9677	.9605
126	.9740	.9672	----------
127	.9736	.9667	----------
128	.9732	.9662	----------
129	.9728	.9657	----------
130	.9724	.9652	----------
131	.9720	.9647	----------
132	.9716	.9642	----------
133	.9713	.9637	----------
134	.9709	.9632	----------
135	.9705	.9627	----------
136	.9701	.9622	----------
137	.9697	.9617	----------
138	.9694	.9613	----------
139	.9690	.9608	----------

Observed temperature in °F.	Volume at 60° F. occupied by unit volume at indicated temperatures: Group I up to 34.9 degrees A. P. I. at 60° F.	Group II 35 to 50.9 degrees A. P. I. at 60° F.
140	0.9686	0.9603
141	.9682	.9598
142	.9678	.9593
143	.9675	.9588
144	.9671	.9583
145	.9667	.9578
146	.9663	.9573
147	.9659	.9568
148	.9655	.9563
149	.9651	.9558
150	.9647	.9553
151	.9643	----------
152	.9639	----------
153	.9636	----------
154	.9632	----------
155	.9628	----------
156	.9624	----------
157	.9620	----------
158	.9616	----------
159	.9612	----------
160	.9608	----------
161	.9604	----------
162	.9601	----------
163	.9597	----------
164	.9594	----------
165	.9590	----------
166	.9586	----------
167	.9582	----------
168	.9578	----------
169	.9574	----------
170	.9570	----------
171	.9566	----------
172	.9562	----------
173	.9559	----------
174	.9555	----------
175	.9551	----------
176	.9547	----------
177	.9543	----------
178	.9540	----------
179	.9536	----------
180	.9532	----------
181	.9528	----------
182	.9524	----------
183	.9521	----------
184	.9517	----------
185	.9513	----------
186	.9509	----------
187	.9505	----------
188	.9502	----------
189	.9498	----------

Abridged Volume Correction Table for Petroleum Oils—Continued

Observed temperature in °F.	Volume at 60° F. occupied by unit volume at indicated temperatures: Group I up to 34.9 degrees A.P.I. at 60° F.
190	0.9494
191	.9490
192	.9487
193	.9483
194	.9480
195	.9476
196	.9472
197	.9468
198	.9465
199	.9461
200	.9457
201	.9453
202	.9449
203	.9446
204	.9442
205	.9438
206	.9434
207	.9430
208	.9427
209	.9423

Observed temperature in °F.	Volume at 60° F. occupied by unit volume at indicated temperatures: Group I up to 34.9 degrees A.P.I. at 60° F.
210	0.9419
211	.9415
212	.9412
213	.9408
214	.9405
215	.9401
216	.9397
217	.9393
218	.9390
219	.9386
220	.9382
221	.9378
222	.9374
223	.9371
224	.9367
225	.9363
226	.9359
227	.9356
228	.9352
229	.9349

Observed temperature in °F.	Volume at 60° F. occupied by unit volume at indicated temperatures: Group I up to 34.9 degrees A.P.I. at 60° F.
230	0.9345
231	.9341
232	.9337
233	.9334
234	.9330
235	.9326
236	.9322
237	.9318
238	.9315
239	.9311
240	.9307
241	.9303
242	.9300
243	.9296
244	.9293
245	.9289
246	.9285
247	.9281
248	.9278
249	.9274
250	.9270

Indicated Specific Gravity of Petroleum Oils at Various Temperatures, Corrected to Specific Gravity at 60°/60°F.

Example: If the hydrometer reads 0.800 Sp. Gr. in a petroleum oil the temperature of which is 82°F., the true Specific Gravity at 60°F. will be 0.800 plus 0.0086 or 0.8086.

This table is based upon the results of experiments carried on at the Bureau of Standards, Washington, D. C., and published in Technologic Paper No. 77 and Circular No. 154.

This investigation has shown that within the limits of ordinary measurements the rate of change of specific gravity with change of temperature is the same for all petroleum oils of the same specific gravity. In the calculation of the expansion table the average rate of expansion found for all oils of each designated specific gravity has been used.

The thermal expansion of the glass of which the hydrometer is made has been taken into account in computing this table.

This table applies to all petroleum oils, both crude and refined, produced in the United States. Each grade of oil, gasoline, illuminating oil, lubricating and fuel oil, etc., falls into its proper place in the tables by reason of its specific gravity.[1]

Although it is generally believed that California oils have a considerably higher rate of expansion than do oils from the Central and Eastern States, this has not been found to be the case, and the slightly higher rate is not sufficient to cause an appreciable error in results carried only to the degree of accuracy here given.

1 In the case of oils containing paraffin, or other materials that become solid at low temperatures, the expansion shown by the tables is somewhat too small at temperatures below the point of solidification.

Indicated Specific Gravity of Petroleum Oils at Various Temperatures, Corrected to Specific Gravity at 60°/60°F.

Indicated Temp. °F.	Indicated Specific Gravity 0.600	0.610	0.620	0.630	0.640
	Subtract from Indicated Specific Gravity				
0	.0366	.0358	.0351	.0343	.0335
2	.0352	.0345	.0338	.0331	.0324
4	.0340	.0333	.0326	.0319	.0312
6	.0327	.0320	.0314	.0307	.0300
8	.0314	.0308	.0301	.0295	.0288
10	.0301	.0295	.0289	.0283	.0276
12	.0288	.0283	.0277	.0271	.0264
14	.0276	.0271	.0265	.0259	.0252
16	.0264	.0258	.0253	.0247	.0242
18	.0251	.0246	.0241	.0235	.0230
20	.0238	.0233	.0228	.0223	.0218
22	.0226	.0221	.0217	.0212	.0207
24	.0214	.0210	.0206	.0201	.0196
26	.0202	.0198	.0194	.0189	.0185
28	.0190	.0186	.0182	.0178	.0174
30	.0178	.0174	.0170	.0166	.0162
32	.0165	.0162	.0158	.0154	.0151
34	.0152	.0150	.0147	.0144	.0140
36	.0140	.0138	.0135	.0132	.0129
38	.0128	.0126	.0124	.0121	.0118
40	.0116	.0114	.0112	.0110	.0107
42	.0105	.0103	.0101	.0099	.0096
44	.0093	.0091	.0089	.0087	.0085
46	.0081	.0080	.0078	.0076	.0074
48	.0070	.0068	.0067	.0065	.0063
50	.0058	.0056	.0055	.0054	.0053
52	.0047	.0046	.0045	.0044	.0043
54	.0035	.0034	.0034	.0033	.0032
56	.0023	.0023	.0022	.0021	.0020
58	.0011	.0011	.0011	.0011	.0010
	Add to Indicated Specific Gravity				
60	0.0000	0.0000	0.0000	0.0000	0.0000
62	.0012	.0011	.0010	.0010	.0010
64	.0024	.0023	.0022	.0022	.0021
66	.0034	.0033	.0033	.0033	.0032
68	.0045	.0044	.0043	.0043	.0042

Indicated Specific Gravity of Petroleum Oils at Various Temperatures, Corrected to Specific Gravity at 60°/60°F.—Continued

Indicated Temp. °F.	Indicated Specific Gravity 0.600	0.610	0.620	0.630	0.640
	Add to Indicated Specific Gravity				
70	.0057	.0055	.0054	.0053	.0052
72	.0068	.0066	.0065	.0064	.0063
74	.0080	.0078	.0076	.0074	.0073
76	.0090	.0088	.0086	.0084	.0083
78	.0101	.0099	.0097	.0095	.0094
80	.0112	.0110	.0108	.0106	.0104
82	.0123	.0120	.0118	.0116	.0114
84	.0135	.0132	.0129	.0126	.0124
86	.0145	.0142	.0139	.0137	.0134
88	.0155	.0152	.0150	.0147	.0144
90	.0166	.0163	.0160	.0157	.0154

Indicated Specific Gravity of Petroleum Oils at Various Temperatures, Corrected to Specific Gravity at 60°/60°F.—Continued

Indicated Temp. °F.	Indicated Specific Gravity 0.650	0.660	0.670	0.680	0.690
	Subtract from Indicated Specific Gravity				
0	.0328	.0320	.0313	.0307	.0301
2	.0317	.0309	.0302	.0296	.0291
4	.0305	.0298	.0291	.0285	.0280
6	.0294	.0287	.0280	.0275	.0270
8	.0282	.0276	.0270	.0265	.0260
10	.0270	.0264	.0259	.0254	.0250
12	.0259	.0253	.0248	.0243	.0239
14	.0248	.0243	.0238	.0233	.0229
16	.0236	.0231	.0226	.0222	.0219
18	.0225	.0220	.0216	.0212	.0209
20	.0214	.0209	.0204	.0201	.0198
22	.0203	.0198	.0194	.0191	.0188
24	.0191	.0187	.0184	.0181	.0178
26	.0180	.0176	.0173	.0171	.0168
28	.0169	.0166	.0163	.0161	.0158
30	.0158	.0155	.0153	.0151	.0148
32	.0148	.0145	.0142	.0140	.0138
34	.0137	.0134	.0132	.0130	.0128
36	.0126	.0123	.0121	.0119	.0117
38	.0115	.0113	.0111	.0109	.0107
40	.0105	.0103	.0101	.0099	.0098
42	.0094	.0092	.0090	.0089	.0088
44	.0083	.0082	.0080	.0079	.0078
46	.0072	.0071	.0070	.0069	.0068
48	.0062	.0061	.0060	.0059	.0058
50	.0052	.0051	.0050	.0050	.0049
52	.0042	.0041	.0040	.0040	.0039
54	.0031	.0030	.0030	.0030	.0029
56	.0020	.0020	.0020	.0020	.0019
58	.0010	.0010	.0010	.0010	.0010
	Add to Indicated Specific Gravity				
60	0.0000	0.0000	0.0000	0.0000	0.0000
62	.0010	.0010	.0010	.0010	.0010
64	.0021	.0020	.0020	.0020	.0020
66	.0031	.0030	.0030	.0030	.0029
68	.0041	.0040	.0040	.0039	.0038

Indicated Specific Gravity of Petroleum Oils at Various Temperatures, Corrected to Specific Gravity at 60°/60°F.—Continued

Indicated Temp. °F.	Indicated Specific Gravity 0.650	0.660	0.670	0.680	0.690
	Add to Indicated Specific Gravity				
70	.0051	.0050	.0050	.0049	.0048
72	.0061	.0060	.0060	.0059	.0058
74	.0071	.0070	.0070	.0069	.0067
76	.0081	.0080	.0079	.0078	.0077
78	.0092	.0091	.0089	.0087	.0086
80	.0102	.0101	.0099	.0097	.0096
82	.0112	.0111	.0109	.0107	.0105
84	.0122	.0121	.0119	.0117	.0115
86	.0132	.0130	.0128	.0126	.0124
88	.0142	.0140	.0138	.0136	.0134
90	.0152	.0150	.0147	.0145	.0143

Indicated Specific Gravity of Petroleum Oils at Various Temperatures, Corrected to Specific Gravity at 60°/60°F.—Continued

Indicated Temp. °F.	Indicated Specific Gravity 0.700	0.710	0.720	0.730	0.740
	Subtract from Indicated Specific Gravity				
0	.0296	.0292	.0288	.0284	.0280
2	.0286	.0282	.0278	.0274	.0270
4	.0276	.0272	.0268	.0264	.0260
6	.0266	.0262	.0259	.0255	.0251
8	.0256	.0252	.0249	.0245	.0241
10	.0246	.0243	.0239	.0235	.0231
12	.0236	.0233	.0229	.0225	.0221
14	.0226	.0223	.0220	.0216	.0213
16	.0216	.0213	.0210	.0206	.0203
18	.0206	.0203	.0200	.0196	.0193
20	.0196	.0193	.0190	.0187	.0184
22	.0186	.0183	.0180	.0177	.0174
24	.0176	.0173	.0170	.0168	.0165
26	.0166	.0163	.0161	.0158	.0155
28	.0156	.0153	.0151	.0148	.0146
30	.0146	.0143	.0141	.0139	.0137
32	.0136	.0134	.0132	.0130	.0128
34	.0126	.0124	.0122	.0120	.0118
36	.0116	.0114	.0112	.0110	.0109
38	.0106	.0104	.0103	.0101	.0100
40	.0097	.0095	.0094	.0092	.0091
42	.0087	.0085	.0084	.0083	.0082
44	.0077	.0076	.0075	.0074	.0072
46	.0067	.0066	.0065	.0064	.0063
48	.0057	.0056	.0055	.0054	.0053
50	.0048	.0047	.0047	.0046	.0045
52	.0038	.0037	.0037	.0036	.0036
54	.0029	.0028	.0028	.0027	.0026
56	.0019	.0018	.0018	.0018	.0017
58	.0010	.0010	.0010	.0010	.0009
	Add to Indicated Specific Gravity				
60	0.0000	0.0000	0.0000	0.0000	0.0000
62	.0009	.0009	.0009	.0009	.0009
64	.0019	.0019	.0019	.0019	.0018
66	.0028	.0028	.0028	.0027	.0026
68	.0038	.0037	.0037	.0036	.0035

Indicated Specific Gravity of Petroleum Oils at Various Temperatures, Corrected to Specific Gravity at 60°/60°F.—Continued

Indicated Temp. °F.	Indicated Specific Gravity 0.700	0.710	0.720	0.730	0.740
	Add to Indicated Specific Gravity				
70	.0048	.0047	.0046	.0045	.0044
72	.0057	.0057	.0056	.0054	.0053
74	.0066	.0065	.0065	.0063	.0061
76	.0075	.0074	.0073	.0072	.0070
78	.0085	.0084	.0083	.0081	.0079
80	.0094	.0093	.0091	.0089	.0087
82	.0103	.0101	.0100	.0098	.0096
84	.0113	.0111	.0109	.0107	.0105
86	.0122	.0120	.0118	.0116	.0114
88	.0132	.0130	.0128	.0125	.0122
90	.0141	.0139	.0136	.0133	.0131
92	.0151	.0148	.0145	.0142	.0139
94	.0160	.0157	.0154	.0151	.0148
96	.0169	.0166	.0163	.0160	.0157
98	.0179	.0176	.0173	.0169	.0165
100	.0188	.0185	.0181	.0177	.0174
102	.0196	.0193	.0189	.0185	.0182
104	.0205	.0202	.0198	.0194	.0190
106	.0214	.0211	.0207	.0203	.0198
108	.0223	.0220	.0216	.0211	.0206
110	.0232	.0228	.0224	.0219	.0215
112	.0240	.0237	.0233	.0228	.0223
114	.0250	.0246	.0241	.0236	.0231
116	.0258	.0254	.0249	.0245	.0239
118	.0266	.0263	.0259	.0253	.0247
120	.0275	.0271	.0267	.0261	.0255
122	.0285	.0280	.0275	.0269	.0263
124	.0293	.0288	.0283	.0277	.0271
126	.0302	.0297	.0291	.0285	.0279
128	.0311	.0306	.0300	.0293	.0287
130	.0319	.0314	.0308	.0301	.0295

Indicated Specific Gravity of Petroleum Oils at Various Temperatures, Corrected to Specific Gravity at 60°/60°F.- Continued

Indicated Temp. °F.	Indicated Specific Gravity 0.750	0.760	0.770	0.780	0.790
	Subtract from Indicated Specific Gravity				
0	.0276	.0272	.0268	.0263	.0257
2	.0266	.0262	.0258	.0253	.0248
4	.0256	.0252	.0248	.0243	.0238
6	.0247	.0243	.0239	.0234	.0229
8	.0237	.0233	.0229	.0225	.0220
10	.0238	.0224	.0220	.0215	.0211
12	.0218	.0215	.0211	.0207	.0202
14	.0210	.0206	.0202	.0197	.0193
16	.0200	.0196	.0192	.0188	.0184
18	.0190	.0186	.0183	.0179	.0176
20	.0181	.0177	.0174	.0171	.0167
22	.0171	.0168	.0165	.0162	.0159
24	.0162	.0159	.0156	.0153	.0150
26	.0153	.0150	.0147	.0144	.0141
28	.0144	.0141	.0138	.0135	.0133
30	.0135	.0132	.0130	.0127	.0124
32	.0126	.0123	.0121	.0118	.0115
34	.0116	.0114	.0112	.0110	.0107
36	.0107	.0105	.0103	.0101	.0099
38	.0098	.0096	.0095	.0093	.0091
40	.0089	.0087	.0086	.0084	.0083
42	.0080	.0078	.0077	.0076	.0074
44	.0071	.0069	.0068	.0067	.0066
46	.0062	.0061	.0060	.0059	.0058
48	.0052	.0051	.0050	.0050	.0049
50	.0044	.0043	.0042	.0041	.0040
52	.0035	.0035	.0034	.0033	.0032
54	.0025	.0025	.0025	.0025	.0024
56	.0017	.0017	.0017	.0017	.0016
58	.0009	.0008	.0008	.0008	.0008
	Add to Indicated Specific Gravity				
60	0.0000	0.0000	0.0000	0.0000	0.0000
62	.0009	.0009	.0008	.0008	.0008
64	.0018	.0017	.0017	.0017	.0016
66	.0026	.0026	.0025	.0025	.0024
68	.0035	.0034	.0033	.0033	.0032

Indicated Specific Gravity of Petroleum Oils at Various Temperatures, Corrected to Specific Gravity at 60°/60°F.—Continued

Indicated Temp. °F.	Indicated Specific Gravity 0.750	0.760	0.770	0.780	0.790
	Add to Indicated Specific Gravity				
70	.0043	.0042	.0041	.0041	.0040
72	.0052	.0051	.0050	.0049	.0048
74	.0060	.0059	.0058	.0057	.0056
76	.0069	.0068	.0066	.0065	.0064
78	.0078	.0076	.0074	.0073	.0071
80	.0086	.0084	.0082	.0081	.0079
82	.0094	.0092	.0090	.0089	.0087
84	.0103	.0101	.0098	.0097	.0095
86	.0112	.0109	.0107	.0105	.0103
88	.0120	.0117	.0115	.0113	.0111
90	.0128	.0125	.0123	.0120	.0118
92	.0136	.0133	.0131	.0128	.0126
94	.0145	.0141	.0139	.0135	.0133
96	.0153	.0150	.0146	.0143	.0140
98	.0162	.0158	.0154	.0150	.0148
100	.0170	.0166	.0162	.0158	.0156
102	.0178	.0174	.0170	.0166	.0164
104	.0186	.0182	.0178	.0174	.0171
106	.0194	.0190	.0186	.0182	.0179
108	.0202	.0198	.0194	.0190	.0187
110	.0210	.0206	.0202	.0198	.0194
112	.0218	.0213	.0209	.0205	.0202
114	.0225	.0220	.0216	.0212	.0209
116	.0233	.0228	.0224	.0219	.0216
118	.0241	.0236	.0232	.0227	.0223
120	.0249	.0244	.0239	.0234	.0231
122	.0257	.0252	.0247	.0242	.0239
124	.0265	.0259	.0254	.0249	.0246
126	.0273	.0267	.0262	.0256	.0252
128	.0281	.0275	.0269	.0264	.0259

Indicated Specific Gravity of Petroleum Oils at Various Temperatures, Corrected to Specific Gravity at 60°/60°F.—Continued

Indicated Temp. °F.	Indicated Specific Gravity 0.750	0.760	0.770	0.780	0.790
	Add to Indicated Specific Gravity				
130	.0289	.0283	0277	.0272	.0267
135				.0290	.0285
140				.0309	.0304
145				.0327	.0322
150				.0344	.0339
155					.0357
160					.0375
165					.0393
170					.0411
175					.0428
180					.0446
185					.0463
190					.0481
195					.0497

Indicated Specific Gravity of Petroleum Oils at Various Temperatures, Corrected to Specific Gravity at 60°/60°F.—Continued

Indicated Temp. °F.	Indicated Specific Gravity 0.800	0.810	0.820	0.830	0.840
	Subtract from Indicated Specific Gravity				
0	.0251	.0245	.0240	.0236	.0232
2	.0242	.0234	.0231	.0227	.0223
4	.0233	.0227	.0222	.0218	.0214
6	.0224	.0218	.0213	.0209	.0206
8	.0215	.0209	.0204	.0201	.0198
10	.0207	.0201	.0196	.0193	.0190
12	.0198	.0193	.0188	.0185	.0182
14	.0188	.0184	.0180	.0177	.0175
16	.0180	.0175	.0172	.0169	.0167
18	.0172	.0167	.0164	.0162	.0160
20	.0164	.0159	.0156	.0154	.0152
22	.0155	.0151	.0148	.0146	.0144
24	.0147	.0143	.0140	.0138	.0136
26	.0138	.0135	.0132	.0130	.0128
28	.0130	.0127	.0124	.0122	.0120
30	.0121	.0119	.0116	.0114	.0112
32	.0113	.0111	.0109	.0107	.0105
34	.0105	.0103	.0101	.0100	.0098
36	.0097	.0095	.0093	.0092	.0090
38	.0089	.0087	.0085	.0084	.0083
40	.0081	.0079	.0077	.0076	.0075
42	.0072	.0071	.0069	.0069	.0067
44	.0064	.0063	.0061	.0062	.0060
46	.0056	.0055	.0053	.0054	.0053
48	.0048	.0047	.0045	.0046	.0045
50	.0040	.0039	.0038	.0038	.0037
52	.0032	.0031	.0030	.0031	.0030
54	.0024	.0024	.0023	.0023	.0023
56	.0016	.0016	.0015	.0015	.0015
58	.0008	.0008	.0008	.0008	.0007
	Add to Indicated Specific Gravity				
60	0.0000	0.0000	0.0000	0.0000	0.0000
62	.0008	.0007	.0007	.0007	.0007
64	.0016	.0015	.0014	.0014	.0014
66	.0024	.0023	.0022	.0022	.0022
68	.0031	.0031	.0030	.0030	.0030

Indicated Specific Gravity of Petroleum Oils at Various Temperatures, Corrected to Specific Gravity at 60°/60°F.—Continued

Indicated Temp. °F.	Indicated Specific Gravity 0.800	0.810	0.820	0.830	0.840
	Add to Indicated Specific Gravity				
70	.0039	.0038	.0037	.0037	.0037
72	.0047	.0046	.0045	.0044	.0044
74	.0055	.0054	.0053	.0052	.0052
76	.0063	.0062	.0061	.0060	.0059
78	.0070	.0069	.0068	.0067	.0066
80	.0078	.0077	.0076	.0075	.0074
82	.0086	.0084	.0083	.0082	.0082
84	.0094	.0092	.0091	.0090	.0089
86	.0101	.0100	.0099	.0098	.0097
88	.0109	.0107	.0105	.0104	.0103
90	.0116	.0114	.0112	.0111	.0110
92	.0123	.0121	.0120	.0119	.0118
94	.0131	.0129	.0127	.0125	.0124
96	.0137	.0136	.0134	.0132	.0131
98	.0145	.0143	.0141	.0139	.0138
100	.0153	.0151	.0148	.0146	.0145
102	.0161	.0158	.0156	.0154	.0153
104	.0168	.0166	.0164	.0162	.0161
106	.0176	.0173	.0170	.0169	.0167
108	.0184	.0181	.0178	.0176	.0174
110	.0191	.0188	.0185	.0183	.0181
112	.0198	.0195	.0193	.0191	.0189
114	.0205	.0202	.0200	.0198	.0196
116	.0213	.0210	.0207	.0205	.0203
118	.0220	.0217	.0215	.0213	.0210
120	.0227	.0224	.0221	.0219	.0217
122	.0235	.0232	.0229	.0227	.0225
124	.0242	.0239	.0235	.0233	.0231
126	.0248	.0245	.0242	.0240	.0238
128	.0255	.0252	.0250	.0248	.0246

Indicated Specific Gravity of Petroleum Oils at Various Temperatures, Corrected to Specific Gravity at 60°/60°F.—Continued

Indicated Temp. °F.	Indicated Specific Gravity 0.800	0.810	0.820	0.830	0.840
	Add to Indicated Specific Gravity				
130	.0263	.0260	.0257	.0255	.0253
135	.0281	.0278	.0275	.0272	.0270
140	.0299	.0296	.0293	.0290	.0288
145	.0318	.0314	.0310	.0307	.0304
150	.0335	.0331	.0327	.0323	.0320
155	.0353	.0349	.0345	.0341	.0338
160	.0370	.0366	.0362	.0359	.0356
165	.0388	.0383	.0379	.0376	.0373
170	.0406	.0401	.0397	.0393	.0390
175	.0423	.0418	.0413	.0410	.0407
180	.0441	.0436	.0431	.0427	.0424
185	.0458	.0453	.0448	.0444	.0441
190	.0476	.0471	.0466	.0462	.0458
195	.0493	.0488	.0483	.0478	.0474

Indicated Specific Gravity of Petroleum Oils at Various Temperatures, Corrected to Specific Gravity at 60°/60°F.—Continued

Indicated Temp. °F.	Indicated Specific Gravity 0.850	0.860	0.870	0.880	0.890
	Subtract from Indicated Specific Gravity				
0	.0229	.0226	.0224	.0222	.0221
2	.0220	.0217	.0215	.0214	.0212
4	.0211	.0209	.0207	.0206	.0204
6	.0203	.0201	.0199	.0198	.0197
8	.0195	.0193	.0192	.0191	.0190
10	.0188	.0186	.0184	.0183	.0182
12	.0180	.0178	.0177	.0176	.0175
14	.0173	.0171	.0169	.0168	.0167
16	.0165	.0163	.0161	.0160	.0159
18	.0158	.0156	.0154	.0153	.0152
20	.0150	.0148	.0147	.0146	.0145
22	.0142	.0140	.0139	.0139	.0138
24	.0135	.0133	.0132	.0131	.0130
26	.0127	.0125	.0124	.0124	.0123
28	.0119	.0118	.0117	.0116	.0115
30	.0111	.0110	.0109	.0109	.0108
32	.0104	.0103	.0102	.0102	.0101
34	.0097	.0096	.0095	.0094	.0094
36	.0089	.0088	.0087	.0087	.0086
38	.0082	.0081	.0080	.0079	.0079
40	.0074	.0073	.0072	.0072	.0072
42	.0066	.0066	.0065	.0065	.0065
44	.0059	.0059	.0058	.0057	.0057
46	.0052	.0051	.0050	.0050	.0050
48	.0045	.0044	.0043	.0043	.0043
50	.0037	.0037	.0036	.0036	.0036
52	.0030	.0030	.0029	.0028	.0028
54	.0022	.0022	.0021	.0021	.0021
56	.0015	.0015	.0014	.0014	.0014
58	.0007	.0007	.0007	.0007	.0007
	Add to Indicated Specific Gravity				
60	0.0000	0.0000	0.0000	0.0000	0.0000
62	.0007	.0007	.0007	.0007	.0007
64	.0014	.0014	.0014	.0014	.0014
66	.0022	.0022	.0022	.0022	.0022
68	.0029	.0029	.0029	.0029	.0029

Indicated Specific Gravity of Petroleum Oils at Various Temperatures, Corrected to Specific Gravity at 60°/60°F.—Continued

Indicated Temp. °F.	Indicated Specific Gravity 0.850	0.860	0.870	0.880	0.890
	Add to Indicated Specific Gravity				
70	.0037	.0037	.0037	.0036	.0036
72	.0044	.0044	.0044	.0043	.0043
74	.0052	.0052	.0052	.0051	.0050
76	.0059	.0059	.0058	.0058	.0058
78	.0066	.0066	.0065	.0065	.0065
80	.0073	.0073	.0073	.0072	.0072
82	.0081	.0080	.0080	.0080	.0079
84	.0088	.0088	.0087	.0087	.0086
86	.0096	.0095	.0094	.0093	.0093
88	.0103	.0102	.0101	.0100	.0100
90	.0110	.0109	.0108	.0107	.0107
92	.0117	.0116	.0115	.0114	.0114
94	.0124	.0123	.0122	.0121	.0120
96	.0130	.0130	.0129	.0128	.0127
98	.0137	.0137	.0136	.0135	.0135
100	.0144	.0143	.0143	.0142	.0142
102	.0152	.0151	.0151	.0150	.0149
104	.0159	.0158	.0157	.0156	.0156
106	.0166	.0165	.0164	.0164	.0163
108	.0173	.0172	.0171	.0171	.0170
110	.0180	.0179	.0178	.0178	.0177
112	.0187	.0186	.0185	.0185	.0184
114	.0194	.0193	.0192	.0192	.0191
116	.0201	.0199	.0198	.0198	.0197
118	.0208	.0206	.0205	.0205	.0204
120	.0215	.0214	.0213	.0212	.0211
122	.0223	.0221	.0220	.0219	.0218
124	.0229	.0228	.0227	.0226	.0225
126	.0236	.0235	.0233	.0232	.0231
128	.0244	.0242	.0240	.0239	.0238

Indicated Specific Gravity of Petroleum Oils at Various Temperatures, Corrected to Specific Gravity at 60°/60°F.—Continued

Indicated Temp. °F.	Indicated Specific Gravity 0.850	0.860	0.870	0.880	0.890
	Add to Indicated Specific Gravity				
130	.0250	.0249	.0248	.0247	.0246
135	.0267	.0266	.0264	.0263	.0262
140	.0286	.0284	.0282	.0281	.0280
145	.0302	.0300	.0298	.0297	.0296
150	.0318	.0316	.0314	.0313	.0312
155	.0335	.0333	.0331	.0330	.0329
160	.0353	.0351	.0349	.0348	.0347
165	.0371	.0368	.0366	.0365	.0364
170	.0387	.0385	.0383	.0382	.0381
175	.0405	.0403	.0401	.0399	.0398
180	.0421	.0419	.0417	.0416	.0415
185	.0438	.0435	.0433	.0431	.0430
190	.0455	.0452	.0450	.0448	.0446
195	.0471	.0469	.0467	.0465	.0463

Indicated Specific Gravity of Petroleum Oils at Various Temperatures, Corrected to Specific Gravity at 60°/60°F.—Continued

Indicated Temp. °F.	Indicated Specific Gravity 0.900	0.910	0.920	0.930	0.940
	Subtract from Indicated Specific Gravity				
0	.0220	.0219	.0218	.0217	.0216
2	.0211	.0211	.0210	.0209	.0208
4	.0203	.0203	.0202	.0201	.0200
6	.0196	.0195	.0194	.0194	.0193
8	.0189	.0188	.0187	.0187	.0187
10	.0181	.0180	.0179	.0179	.0179
12	.0174	.0173	.0172	.0172	.0172
14	.0166	.0166	.0165	.0165	.0165
16	.0158	.0158	.0158	.0158	.0158
18	.0151	.0151	.0151	.0151	.0151
20	.0144	.0144	.0144	.0144	.0144
22	.0137	.0136	.0136	.0136	.0136
24	.0130	.0129	.0129	.0129	.0129
26	.0122	.0122	.0122	.0122	.0122
28	.0114	.0114	.0114	.0114	.0114
30	.0107	.0107	.0107	.0107	.0107
32	.0100	.0100	.0100	.0100	.0100
34	.0093	.0093	.0093	.0093	.0093
36	.0085	.0085	.0086	.0086	.0086
38	.0078	.0078	.0078	.0078	.0078
40	.0071	.0071	.0071	.0071	.0071
42	.0064	.0064	.0064	.0064	.0064
44	.0057	.0057	.0057	.0057	.0057
46	.0050	.0050	.0050	.0050	.0050
48	.0043	.0043	.0043	.0043	.0043
50	.0036	.0036	.0036	.0036	.0035
52	.0028	.0028	.0028	.0028	.0028
54	.0021	.0021	.0021	.0021	.0021
56	.0014	.0014	.0014	.0014	.0014
58	.0007	.0007	.0007	.0007	.0007
	Add to Indicated Specific Gravity				
60	0.0000	0.0000	0.0000	0.0000	0.0000
62	.0007	.0007	.0007	.0007	.0007
64	.0014	.0014	.0014	.0014	.0014
66	.0022	.0021	.0021	.0021	.0021
68	.0029	.0028	.0028	.0028	.0028

Indicated Specific Gravity of Petroleum Oils at Various Temperatures, Corrected to Specific Gravity at 60°/60°F.—Continued

Indicated Temp. °F.	Indicated Specific Gravity 0.900	0.910	0.920	0.930	0.940
	Add to Indicated Specific Gravity				
70	.0036	.0036	.0035	.0035	.0035
72	.0043	.0043	.0042	.0042	.0042
74	.0050	.0050	.0050	.0050	.0050
76	.0057	.0057	.0057	.0057	.0056
78	.0064	.0064	.0064	.0064	.0063
80	.0072	.0071	.0071	.0070	.0070
82	.0079	.0079	.0079	.0078	.0077
84	.0085	.0085	.0085	.0085	.0085
86	.0092	.0092	.0092	.0092	.0091
88	.0099	.0099	.0099	.0099	.0099
90	.0106	.0106	.0106	.0106	.0105
92	.0114	.0114	.0114	.0113	.0113
94	.0120	.0120	.0120	.0120	.0119
96	.0127	.0127	.0127	.0127	.0126
98	.0135	.0134	.0134	.0134	.0133
100	.0141	.0141	.0140	.0140	.0140
102	.0148	.0147	.0147	.0147	.0146
104	.0155	.0155	.0154	.0154	.0154
106	.0162	.0161	.0160	.0160	.0160
108	.0169	.0168	.0167	.0167	.0167
110	.0176	.0175	.0174	.0174	.0174
112	.0183	.0182	.0181	.0181	.0181
114	.0189	.0189	.0188	.0188	.0187
116	.0196	.0195	.0194	.0194	.0194
118	.0202	.0202	.0201	.0200	.0200
120	.0210	.0209	.0208	.0208	.0207
122	.0217	.0217	.0216	.0216	.0215
124	.0224	.0223	.0222	.0222	.0222
126	.0230	.0230	.0229	.0228	.0228
128	.0237	.0236	.0235	.0235	.0235

Indicated Specific Gravity of Petroleum Oils at Various Temperatures, Corrected to Specific Gravity at 60°/60°F.—Continued

Indicated Temp. °F.	Indicated Specific Gravity 0.900	0.910	0.920	0.930	0.940
	Add to Indicated Specific Gravity				
130	.0245	.0244	.0243	.0243	.0242
135	.0261	.0260	.0259	.0259	.0259
140	.0279	.0278	.0277	.0277	.0276
145	.0295	.0294	.0293	.0292	.0292
150	.0312	.0311	.0311	.0310	.0310
155	.0328	.0328	.0327	.0327	.0326
160	.0346	.0345	.0345	.0344	.0344
165	.0363	.0362	.0361	.0361	.0360
170	.0380	.0379	.0378	.0377	.0376
175	.0396	.0395	.0394	.0393	.0392
180	.0413	.0411	.0410	.0409	.0408
185	.0429	.0427	.0426	.0425	.0424
190	.0445	.0444	.0443	.0441	.0440
195	.0462	.0460	.0459	.0458	.0456

Indicated Specific Gravity of Petroleum Oils at Various Temperatures, Corrected to Specific Gravity at 60°/60°F.—Continued

Indicated Temp. °F.	Indicated Specific Gravity 0.950	0.960	0.970	0.980	0.990
	Subtract from Indicated Specific Gravity				
0	.0215	.0214	.0214	.0214	.0214
2	.0208	.0208	.0208	.0208	.0208
4	.0200	.0200	.0200	.0200	.0200
6	.0193	.0193	.0193	.0193	.0193
8	.0187	.0187	.0187	.0187	.0187
10	.0179	.0179	.0179	.0179	.0179
12	.0172	.0172	.0172	.0172	.0172
14	.0165	.0165	.0165	.0165	.0165
16	.0158	.0158	.0158	.0157	.0157
18	.0151	.0151	.0151	.0150	.0150
20	.0144	.0144	.0144	.0143	.0143
22	.0136	.0136	.0136	.0135	.0135
24	.0129	.0129	.0129	.0128	.0128
26	.0122	.0122	.0122	.0121	.0121
28	.0114	.0114	.0114	.0113	.0113
30	.0107	.0107	.0107	.0106	.0106
32	.0100	.0100	.0099	.0099	.0099
34	.0093	.0093	.0093	.0092	.0092
36	.0086	.0086	.0086	.0085	.0084
38	.0078	.0078	.0078	.0077	.0077
40	.0071	.0071	.0071	.0070	.0070
42	.0064	.0064	.0064	.0063	.0063
44	.0057	.0057	.0057	.0056	.0056
46	.0050	.0050	.0050	.0049	.0049
48	.0043	.0043	.0043	.0043	.0043
50	.0035	.0035	.0035	.0035	.0035
52	.0028	.0028	.0028	.0028	.0028
54	.0021	.0021	.0021	.0021	.0021
56	.0014	.0014	.0014	.0014	.0014
58	.0007	.0007	.0007	.0007	.0007
	Add to Indicated Specific Gravity				
60	0.0000	0.0000	0.0000	0.0000	0.0000
62	.0007	.0007	.0007	.0007	.0007
64	.0014	.0014	.0014	.0014	.0014
66	.0021	.0021	.0021	.0021	.0021
68	.0028	.0028	.0028	.0028	.0028

Indicated Specific Gravity of Petroleum Oils at Various Temperatures, Corrected to Specific Gravity at 60°/60°F.—Continued

Indicated Temp. °F.	Indicated Specific Gravity				
	0.950	0.960	0.970	0.980	0.990
	Add to Indicated Specific Gravity				
70	.0035	.0035	.0035	.0035	.0035
72	.0042	.0042	.0042	.0042	.0042
74	.0049	.0049	.0049	.0049	.0049
76	.0056	.0056	.0056	.0056	.0056
78	.0063	.0063	.0063	.0063	.0063
80	.0070	.0070	.0070	.0070	.0070
82	.0077	.0077	.0077	.0077	.0077
84	.0084	.0084	.0084	.0084	.0084
86	.0091	.0091	.0091	.0091	.0091
88	.0098	.0098	.0098	.0098	.0098
90	.0105	.0104	.0104	.0104	.0104
92	.0112	.0112	.0112	.0112	.0112
94	.0118	.0118	.0118	.0118	.0118
96	.0125	.0125	.0125	.0125	.0125
98	.0133	.0132	.0132	.0132	.0132
100	.0139	.0139	.0139	.0139	.0139
102	.0146	.0146	.0146	.0146	.0146
104	.0153	.0153	.0153	.0153	.0153
106	.0159	.0159	.0159	.0159	.0159
108	.0166	.0166	.0166	.0166	.0166
110	.0173	.0173	.0173	.0173	.0173
112	.0180	.0180	.0180	.0180	.0179
114	.0187	.0187	.0187	.0187	.0187
116	.0194	.0194	.0194	.0194	.0194
118	.0200	.0200	.0200	.0200	.0200
120	.0207	.0207	.0207	.0207	.0207
122	.0215	.0215	.0214	.0214	.0214
124	.0221	.0221	.0221	.0220	.0220
126	.0228	.0228	.0227	.0227	.0227
128	.0235	.0235	.0234	.0234	.0234

Indicated Specific Gravity of Petroleum Oils at Various Temperatures, Corrected to Specific Gravity at 60°/60°F.—Continued

Indicated Temp. °F.	Indicated Specific Gravity				
	0.950	0.960	0.970	.0980	0.990
	Add to Indicated Specific Gravity				
130	.0242	.0241	.0241	.0241	.0241
135	.0259	.0258	.0258	.0257	.0257
140	.0275	.0275	.0275	.0274	.0274
145	.0292	.0291	.0291	.0290	.0290
150	.0309	.0308	.0308	.0308	.0307
155	.0325	.0325	.0325	.0324	.0324
160	.0343	.0342	.0341	.0340	.0340
165	.0359	.0358	.0357	.0356	.0355
170	.0375	.0374	.0373	.0372	.0371
175	.0391	.0389	.0388	.0387	.0387
180	.0406	.0405	.0404	.0403	.0403
185	.0422	.0421	.0420	.0420	.0419
190	.0438	.0437	.0436	.0435	.0435
195	.0454	.0453	.0452	.0451	.0451

Specific Gravity Equivalents for Degrees Baumé for Liquids Lighter than Water

*Temperature 60°/60° F.

$$\text{Degrees Baumé} = \frac{140}{\text{Sp. Gr. } 60°/60° \text{ F.}} - 130$$

$$\text{Sp. Gr. } 60°/60° \text{ F.} = \frac{140}{130 + ° \text{ Be.}}$$

Degrees Baumé	Tenths of degrees Baumé									
	0	1	2	3	4	5	6	7	8	9
10	1.0000	0.9993	0.9986	0.9979	0.9972	0.9964	0.9957	0.9950	0.9943	0.9936
11	.9929	.9922	.9915	.9908	.9901	.9894	.9887	.9880	.9873	.9866
12	.9859	.9852	.9845	.9838	.9831	.9825	.9818	.9811	.9804	.9797
13	.9790	.9783	.9777	.9770	.9763	.9756	.9749	.9743	.9736	.9729
14	.9722	.9715	.9709	.9702	.9695	.9689	.9682	.9675	.9669	.9662
15	.9655	.9649	.9642	.9635	.9629	.9622	.9615	.9609	.9602	.9596
16	.9589	.9582	.9576	.9569	.9563	.9556	.9550	.9543	.9537	.9530
17	.9524	.9517	.9511	.9504	.9498	.9492	.9485	.9479	.9472	.9466
18	.9459	.9453	.9447	.9440	.9434	.9428	.9421	.9415	.9409	.9402
19	.9396	.9390	.9383	.9377	.9371	.9365	.9358	.9352	.9346	.9340
20	.9333	.9327	.9321	.9315	.9309	.9302	.9296	.9290	.9284	.9278
21	.9272	.9265	.9259	.9253	.9247	.9241	.9235	.9229	.9223	.9217
22	.9211	.9204	.9198	.9192	.9186	.9180	.9174	.9168	.9162	.9156
23	.9150	.9144	.9138	.9132	.9126	.9121	.9115	.9109	.9103	.9097
24	.9091	.9085	.9079	.9073	.9067	.9061	.9056	.9050	.9044	.9038
25	.9032	.9026	.9021	.9015	.9009	.9003	.8997	.8992	.8986	.8980
26	.8974	.8969	.8963	.8957	.8951	.8946	.8940	.8934	.8929	.8923
27	.8917	.8912	.8906	.8900	.8895	.8889	.8883	.8878	.8872	.8866
28	.8861	.8855	.8850	.8844	.8838	.8833	.8827	.8822	.8816	.8811
29	.8805	.8799	.8794	.8788	.8783	.8777	.8772	.8766	.8761	.8755
30	.8750	.8745	.8739	.8734	.8728	.8723	.8717	.8712	.8706	.8701
31	.8696	.8690	.8685	.8679	.8674	.8669	.8663	.8658	.8653	.8647
32	.8642	.8637	.8631	.8626	.8621	.8615	.8610	.8605	.8600	.8594
33	.8589	.8584	.8578	.8573	.8568	.8563	.8557	.8552	.8547	.8542
34	.8537	.8531	.8526	.8521	.8516	.8511	.8505	.8500	.8495	.8490
35	.8485	.8480	.8475	.8469	.8464	.8459	.8454	.8449	.8444	.8439
36	.8434	.8429	.8424	.8419	.8413	.8408	.8403	.8398	.8393	.8388
37	.8383	.8378	.8373	.8368	.8363	.8358	.8353	.8348	.8343	.8338
38	.8333	.8328	.8323	.8318	.8314	.8309	.8304	.8299	.8294	.8289
39	.8284	.8279	.8274	.8269	.8264	.8260	.8255	.8250	.8245	.8240
40	.8235	.8230	.8226	.8221	.8216	.8211	.8206	.8202	.8197	.8192
41	.8187	.8182	.8178	.8173	.8168	.8163	.8159	.8154	.8149	.8144
42	.8140	.8135	.8130	.8125	.8121	.8116	.8111	.8107	.8102	.8097
43	.8092	.8088	.8083	.8078	.8074	.8069	.8065	.8060	.8055	.8051
44	.8046	.8041	.8037	.8032	.8028	.8023	.8018	.8014	.8009	.8005
45	.8000	.7995	.7991	.7986	.7982	.7977	.7973	.7968	.7964	.7959
46	.7955	.7950	.7946	.7941	.7937	.7932	.7928	.7923	.7919	.7914
47	.7910	.7905	.7901	.7896	.7892	.7887	.7883	.7878	.7874	.7870
48	.7865	.7861	.7856	.7852	.7848	.7843	.7839	.7834	.7830	.7826
49	.7821	.7817	.7812	.7808	.7804	.7799	.7795	.7791	.7786	.7782
50	.7778	.7773	.7769	.7765	.7761	.7756	.7752	.7748	.7743	.7739
51	.7735	.7731	.7726	.7722	.7718	.7713	.7709	.7705	.7701	.7697
52	.7692	.7688	.7684	.7680	.7675	.7671	.7667	.7663	.7659	.7654
53	.7650	.7646	.7642	.7638	.7634	.7629	.7625	.7621	.7617	.7613
54	.7609	.7605	.7600	.7596	.7592	.7588	.7584	.7580	.7576	.7572

*All readings taken at 60°F. and referred to distilled water at 60°F. as 1.0000.

Specific Gravity Equivalents for Degrees Baumé for Liquids Lighter than Water—Continued

Degrees Baumé	Tenths of degrees Baumé									
	0	1	2	3	4	5	6	7	8	9
55	0.7568	0.7563	0.7559	0.7555	0.7551	0.7547	0.7543	0.7539	0.7535	0.7531
56	.7527	.7523	.7519	.7515	.7511	.7507	.7503	.7499	.7495	.7491
57	.7487	.7483	.7479	.7475	.7471	.7467	.7463	.7459	.7455	.7451
58	.7447	.7443	.7439	.7435	.7431	.7427	.7423	.7419	.7415	.7411
59	.7407	.7403	.7400	.7396	.7392	.7388	.7384	.7380	.7376	.7372
60	.7368	.7365	.7361	.7357	.7353	.7349	.7345	.7341	.7338	.7334
61	.7330	.7326	.7322	.7318	.7315	.7311	.7307	.7303	.7299	.7295
62	.7292	.7288	.7284	.7280	.7277	.7273	.7269	.7265	.7261	.7258
63	.7254	.7250	.7246	.7243	.7239	.7235	.7231	.7228	.7224	.7220
64	.7216	.7213	.7209	.7205	.7202	.7198	.7194	.7191	.7187	.7183
65	.7179	.7176	.7172	.7168	.7165	.7161	.7157	.7154	.7150	.7147
66	.7143	.7139	.7136	.7132	.7128	.7125	.7121	.7117	.7114	.7110
67	.7107	.7103	.7099	.7096	.7092	.7089	.7085	.7081	.7078	.7074
68	.7071	.7067	.7064	.7060	.7056	.7053	.7049	.7046	.7042	.7039
69	.7035	.7032	.7028	.7025	.7021	.7018	.7014	.7011	.7007	.7004
70	.7000	.6997	.6993	.6990	.6986	.6983	.6979	.6976	.6972	.6969
71	.6965	.6962	.6958	.6955	.6951	.6948	.6944	.6941	.6938	.6934
72	.6931	.6927	.6924	.6920	.6917	.6914	.6910	.6907	.6903	.6900
73	.6897	.6893	.6890	.6886	.6883	.6880	.6876	.6873	.6869	.6866
74	.6863	.6859	.6856	.6853	.6849	.6846	.6843	.6839	.6836	.6833
75	.6829	.6826	.6823	.6819	.6816	.6813	.6809	.6806	.6803	.6799
76	.6796	.6793	.6790	.6786	.6783	.6780	.6776	.6773	.6770	.6767
77	.6763	.6760	.6757	.6753	.6750	.6747	.6744	.6740	.6737	.6734
78	.6731	.6728	.6724	.6721	.6718	.6715	.6711	.6708	.6705	.6702
79	.6699	.6695	.6692	.6689	.6686	.6683	.6679	.6676	.6673	.6670
80	.6667	.6663	.6660	.6657	.6654	.6651	.6648	.6645	.6641	.6638
81	.6635	.6632	.6629	.6626	.6623	.6619	.6616	.6613	.6610	.6607
82	.6604	.6601	.6598	.6594	.6591	.6588	.6585	.6582	.6579	.6576
83	.6573	.6570	.6567	.6564	.6560	.6557	.6554	.6551	.6548	.6545
84	.6542	.6539	.6536	.6533	.6530	.6527	.6524	.6521	.6518	.6515
85	.6512	.6509	.6506	.6503	.6500	.6497	.6494	.6490	.6487	.6484
86	.6482	.6479	.6476	.6473	.6470	.6467	.6464	.6461	.6458	.6455
87	.6452	.6449	.6446	.6443	.6440	.6437	.6434	.6431	.6428	.6425
88	.6422	.6419	.6416	.6413	.6410	.6407	.6404	.6401	.6399	.6396
89	.6393	.6390	.6387	.6384	.6381	.6378	.6375	.6372	.6369	.6367
90	.6364	.6361	.6358	.6355	.6352	.6349	.6346	.6343	.6341	.6338
91	.6335	.6332	.6329	.6326	.6323	.6321	.6318	.6315	.6312	.6309
92	.6306	.6303	.6301	.6298	.6295	.6292	.6289	.6286	.6284	.6281
93	.6278	.6275	.6272	.6270	.6267	.6264	.6261	.6258	.6256	.6253
94	.6250	.6247	.6244	.6242	.6239	.6236	.6233	.6231	.6228	.6225
95	.6222	.6219	.6217	.6214	.6211	.6208	.6206	.6203	.6200	.6197
96	.6195	.6192	.6189	.6186	.6184	.6181	.6178	.6176	.6173	.6170
97	.6167	.6165	.6162	.6159	.6157	.6154	.6151	.6148	.6146	.6143
98	.6140	.6138	.6135	.6132	.6130	.6127	.6124	.6122	.6119	.6116
99	.6114	.6111	.6108	.6106	.6103	.6100	.6098	.6095	.6092	.6090
100	.6087	-------	-------	-------	-------	-------	-------	-------	-------	-------

Specific Gravity Equivalents for Degrees Baumé for Liquids Heavier than Water

*Temperature 60°/60°F.

One gallon distilled water at 60°F. in air=8.32823 lbs.

Table adopted by the U. S. Bureau of Standards from the formula:

$$\text{°Baumé} = 145 - \frac{145}{\text{Sp. Gr. } 60°/60°\text{F.}}$$

Degrees Baumé	Tenths of Degrees Baumé				
	0	1	2	3	4
0	1.0000	1.0007	1.0014	1.0021	1.0028
1	1.0069	1.0076	1.0083	1.0090	1.0097
2	1.0140	1.0147	1.0154	1.0161	1.0168
3	1.0211	1.0218	1.0226	1.0233	1.0240
4	1.0284	1.0291	1.0298	1.0306	1.0313
5	1.0357	1.0365	1.0372	1.0379	1.0387
6	1.0432	1.0439	1.0447	1.0454	1.0462
7	1.0507	1.0515	1.0522	1.0530	1.0538
8	1.0584	1.0592	1.0599	1.0607	1.0615
9	1.0662	1.0670	1.0677	1.0685	1.0693
10	1.0741	1.0749	1.0757	1.0765	1.0773
11	1.0821	1.0829	1.0837	1.0845	1.0853
12	1.0902	1.0910	1.0919	1.0927	1.0935
13	1.0985	1.0993	1.1002	1.1010	1.1018
14	1.1069	1.1077	1.1086	1.1094	1.1103
15	1.1154	1.1162	1.1171	1.1180	1.1188
16	1.1240	1.1249	1.1258	1.1267	1.1275
17	1.1328	1.1337	1.1346	1.1355	1.1364
18	1.1417	1.1426	1.1435	1.1444	1.1453
19	1.1508	1.1517	1.1526	1.1535	1.1545
20	1.1600	1.1609	1.1619	1.1628	1.1637
21	1.1694	1.1703	1.1712	1.1722	1.1731
22	1.1789	1.1798	1.1808	1.1817	1.1827
23	1.1885	1.1895	1.1905	1.1915	1.1924
24	1.1983	1.1993	1.2003	1.2013	1.2023
25	1.2083	1.2093	1.2104	1.2114	1.2124
26	1.2185	1.2195	1.2205	1.2216	1.2226
27	1.2288	1.2299	1.2309	1.2319	1.2330
28	1.2393	1.2404	1.2414	1.2425	1.2436
29	1.2500	1.2511	1.2522	1.2532	1.2543
30	1.2609	1.2620	1.2631	1.2642	1.2653
31	1.2719	1.2730	1.2742	1.2753	1.2764
32	1.2832	1.2843	1.2855	1.2866	1.2877
33	1.2946	1.2958	1.2970	1.2981	1.2993
34	1.3063	1.3075	1.3087	1.3098	1.3110
35	1.3182	1.3194	1.3206	1.3218	1.3230

*All densities taken at 60°F. and referred to distilled water at 60°F. as 1.0000.

Specific Gravity Equivalents for Degrees Baumé for Liquids Heavier than Water—Continued

Degrees Baumé	Tenths of Degrees Baumé				
	5	6	7	8	9
0	1.0035	1.0042	1.0049	1.0055	1.0062
1	1.0105	1.0112	1.0119	1.0126	1.0133
2	1.0175	1.0183	1.0190	1.0197	1.0204
3	1.0247	1.0255	1.0262	1.0269	1.0276
4	1.0320	1.0328	1.0335	1.0342	1.0350
5	1.0394	1.0402	1.0409	1.0417	1.0424
6	1.0469	1.0477	1.0484	1.0492	1.0500
7	1.0545	1.0553	1.0561	1.0569	1.0576
8	1.0623	1.0630	1.0638	1.0646	1.0654
9	1.0701	1.0709	1.0717	1.0725	1.0733
10	1.0781	1.0789	1.0797	1.0805	1.0813
11	1.0861	1.0870	1.0878	1.0886	1.0894
12	1.0943	1.0952	1.0960	1.0968	1.0977
13	1.1027	1.1035	1.1043	1.1052	1.1060
14	1.1111	1.1120	1.1128	1.1137	1.1145
15	1.1197	1.1206	1.1214	1.1223	1.1232
16	1.1284	1.1293	1.1302	1.1310	1.1319
17	1.1373	1.1381	1.1390	1.1399	1.1408
18	1.1462	1.1472	1.1481	1.1490	1.1499
19	1.1554	1.1563	1.1572	1.1581	1.1591
20	1.1647	1.1656	1.1665	1.1675	1.1684
21	1.1741	1.1750	1.1760	1.1769	1.1779
22	1.1837	1.1846	1.1856	1.1866	1.1876
23	1.1934	1.1944	1.1954	1.1964	1.1974
24	1.2033	1.2043	1.2053	1.2063	1.2073
25	1.2134	1.2144	1.2154	1.2164	1.2175
26	1.2236	1.2247	1.2257	1.2267	1.2278
27	1.2340	1.2351	1.2361	1.2372	1.2383
28	1.2446	1.2457	1.2468	1.2478	1.2489
29	1.2554	1.2565	1.2576	1.2587	1.2598
30	1.2664	1.2675	1.2686	1.2697	1.2708
31	1.2775	1.2787	1.2798	1.2809	1.2821
32	1.2889	1.2900	1.2912	1.2923	1.2935
33	1.3004	1.3016	1.3028	1.3040	1.3051
34	1.3122	1.3134	1.3146	1.3158	1.3170
35	1.3242	1.3254	1.3266	1.3278	1.3291

Specific Gravity Equivalents for Degrees Baumé for Liquids Heavier than Water—Continued

Degrees Baumé	Tenths of Degrees Baumé				
	0	1	2	3	4
36	1.3303	1.3315	1.3327	1.3339	1.3352
37	1.3426	1.3438	1.3451	1.3463	1.3476
38	1.3551	1.3564	1.3577	1.3590	1.3602
39	1.3679	1.3692	1.3705	1.3718	1.3731
40	1.3810	1.3823	1.3836	1.3849	1.3862
41	1.3942	1.3956	1.3969	1.3983	1.3996
42	1.4078	1.4091	1.4105	1.4119	1.4133
43	1.4216	1.4230	1.4244	1.4258	1.4272
44	1.4356	1.4371	1.4385	1.4399	1.4414
45	1.4500	1.4515	1.4529	1.4544	1.4558
46	1.4646	1.4661	1.4676	1.4691	1.4706
47	1.4796	1.4811	1.4826	1.4841	1.4857
48	1.4948	1.4964	1.4979	1.4995	1.5010
49	1.5104	1.5120	1.5136	1.5152	1.5167
50	1.5263	1.5279	1.5295	1.5312	1.5328
51	1.5426	1.5442	1.5458	1.5475	1.5491
52	1.5591	1.5608	1.5625	1.5642	1.5659
53	1.5761	1.5778	1.5795	1.5812	1.5830
54	1.5934	1.5952	1.5969	1.5987	1.6004
55	1.6111	1.6129	1.6147	1.6165	1.6183
56	1.6292	1.6310	1.6329	1.6347	1.6366
57	1.6477	1.6496	1.6515	1.6534	1.6553
58	1.6667	1.6686	1.6705	1.6724	1.6744
59	1.6860	1.6880	1.6900	1.6919	1.6939
60	1.7059	1.7079	1.7099	1.7119	1.7139
61	1.7262	1.7282	1.7303	1.7324	1.7344
62	1.7470	1.7491	1.7512	1.7533	1.7554
63	1.7683	1.7705	1.7726	1.7748	1.7770
64	1.7901	1.7923	1.7946	1.7968	1.7990
65	1.8125	1.8148	1.8170	1.8193	1.8216
66	1.8354	1.8378	1.8401	1.8424	1.8448
67	1.8590	1.8614	1.8638	1.8662	1.8686
68	1.8831	1.8856	1.8880	1.8905	1.8930
69	1.9079	1.9104	1.9129	1.9155	1.9180
70	1.9333				

Specific Gravity Equivalents for Degrees Baumé for Liquids Heavier than Water—Continued

Degrees Baumé	Tenths of Degrees Baumé				
	5	6	7	8	9
36	1.3364	1.3376	1.3389	1.3401	1.3414
37	1.3488	1.3501	1.3514	1.3526	1.3539
38	1.3615	1.3628	1.3641	1.3653	1.3666
39	1.3744	1.3757	1.3770	1.3783	1.3796
40	1.3876	1.3889	1.3902	1.3916	1.3929
41	1.4010	1.4023	1.4037	1.4050	1.4064
42	1.4146	1.4160	1.4174	1.4188	1.4202
43	1.4286	1.4300	1.4314	1.4328	1.4342
44	1.4428	1.4442	1.4457	1.4471	1.4486
45	1.4573	1.4588	1.4602	1.4617	1.4632
46	1.4721	1.4736	1.4751	1.4766	1.4781
47	1.4872	1.4887	1.4902	1.4918	1.4933
48	1.5026	1.5041	1.5057	1.5073	1.5088
49	1.5183	1.5199	1.5215	1.5231	1.5247
50	1.5344	1.5360	1.5376	1.5393	1.5409
51	1.5508	1.5525	1.5541	1.5558	1.5575
52	1.5676	1.5693	1.5710	1.5727	1.5744
53	1.5847	1.5864	1.5882	1.5899	1.5917
54	1.6022	1.6040	1.6058	1.6075	1.6093
55	1.6201	1.6219	1.6237	1.6256	1.6274
56	1.6384	1.6403	1.6421	1.6440	1.6459
57	1.6571	1.6590	1.6609	1.6628	1.6648
58	1.6763	1.6782	1.6802	1.6821	1.6841
59	1.6959	1.6979	1.6999	1.7019	1.7039
60	1.7160	1.7180	1.7200	1.7221	1.7241
61	1.7365	1.7386	1.7407	1.7428	1.7449
62	1.7576	1.7597	1.7618	1.7640	1.7661
63	1.7791	1.7813	1.7835	1.7857	1.7879
64	1.8012	1.8035	1.8057	1.8080	1.8102
65	1.8239	1.8262	1.8285	1.8308	1.8331
66	1.8471	1.8495	1.8519	1.8542	1.8566
67	1.8710	1.8734	1.8758	1.8782	1.8807
68	1.8954	1.8979	1.9004	1.9029	1.9054
69	1.9205	1.9231	1.9256	1.9282	1.9308

True Specific Gravity

All specific gravity values given in the tables in this book are as would be indicated by hydrometers certified by the U. S. Bureau of Standards for true specific gravity.

True specific gravity is defined as the ratio of the weight (in vacuo) of equal volumes of a liquid and of pure water at a standard temperature (usually 60° F.) made against brass weights (in vacuo.)

Apparent Specific Gravity

Specific Gravity value given by a pyctnometer, or weighing bottle, are apparent specific gravities.

This is defined as the ratio of the weight in air (of 50% humidity at the standard temperature and a barometer pressure of 760 m.m. or 29.92 inches of mercury) of equal volumes of a liquid and of pure water at a standard temperature (usually 60° F.) made against brass weights of 8.4 density under the same conditions.

To convert one to the other, the following formulae will give accurate results to the fourth decimal place:

Let T. D. = true specific gravity.
A. D. = apparent specific gravity.

True specific gravity to apparent specific gravity:

$$\text{A. D.} = \text{T. D.} + .0012\,(\text{T. D.} - 1.0000)$$

Example 1.

$$\text{T. D.} = 0.8068$$
$$\text{A. D.} = 0.8068 + .0012\,(0.8068 - 1.0000)$$
$$= 0.8068 + .0012\,(-.1932)$$
$$= 0.8068 + (-.00023)$$
$$= 0.80657$$

Example 2.

$$\text{T. D.} = 1.4044$$
$$\text{A. D.} = 1.4044 + .0012\,(1.4044 - 1.0000)$$
$$= 1.4044 + .0012\,(.4044)$$
$$= 1.4044 + .00048$$
$$= 1.40488$$

Apparent specific gravity to true specific gravity:

$$\text{T. D.} = \text{A. D.} + .0012\,(1.0000 - \text{A. D.})$$

Example 1.

$$\text{A. D.} = 0.80657$$
$$\text{T. D.} = 0.80657 + .0012\,(1.00000 - 0.80657)$$
$$= 0.80657 + .0012\,(.19343)$$
$$= 0.80657 + .00023$$
$$= 0.8068$$

Example 2.

$$\text{A. D.} = 1.4049$$
$$\text{T. D.} = 1.4049 + .0012\,(1.0000 - 1.4049)$$
$$= 1.4049 + .0012\,(-.4049)$$
$$= 1.4049 + (-.00048)$$
$$= 1.40442$$

Density (in grams per milliliter) of Water at Temperatures from 0° to 102° C.*

Temp., Degrees C.	Density	Temp., Degrees C.	Density	Temp., Degrees C.	Density
0	0.99987	35	0.99406	70	0.97781
1	.99993	36	.99371	71	.97723
2	.99997	37	.99336	72	.97666
3	.99999	38	.99299	73	.97607
4	1.00000	39	.99262	74	.97548
5	.99999	40	.99224	75	.97489
6	.99997	41	.99186	76	.97428
7	.99993	42	.99147	77	.97368
8	.99988	43	.99107	78	.97307
9	.99981	44	.99066	79	.97245
10	.99973	45	.99024	80	.97183
11	.99963	46	.98982	81	.97120
12	.99952	47	.98940	82	.97057
13	.99940	48	.98896	83	.96994
14	.99927	49	.98852	84	.96930
15	.99913	50	.98807	85	.96865
16	.99897	51	.98762	86	.96800
17	.99880	52	.98715	87	.96734
18	.99862	53	.98669	88	.96668
19	.99843	54	.98621	89	.96601
20	.99823	55	.98573	90	.96534
21	.99802	56	.98524	91	.96467
22	.99780	57	.98478	92	.96399
23	.99756	58	.98425	93	.96330
24	.99732	59	.98375	94	.96261
25	.99707	60	.98324	95	.96192
26	.99681	61	.98272	96	.96122
27	.99654	62	.98220	97	.96051
28	.99626	63	.98167	98	.95981
29	.99597	64	.98113	99	.95909
30	.99567	65	.98059	100	.95838
31	.99537	66	.98005	101	.95765
32	.99505	67	.97950	102	.95693
33	.99473	68	.97894		
34	.99440	69	.97838		

*According to M. Thiesen, Wiss. Abh. der Physikalich-Technischen Riechsanstalt, 4, No. 1, 1904.
Bureau of Standards, Circular No. 19, 6th Edition.

Conversion of Specific Gravity Hydrometer Readings to Various Temperatures of Standardization

Corrections to be added to readings of a hydrometer standardized at one temperature to convert them to values standardized at another temperature.

The first column shows Specific Gravity at temperature 60°/60°F*. The other columns show the corrections to be applied to indications of a hydrometer standardized at 60°/60°F. to convert it to the standard temperature shown at top of each column.

To convert indications of hydrometers standardized at other than 60°/60°F., add the algebraic difference between the correction for the temperature of standardization desired and the correction for the temperature of standardization of the hydrometer with which the reading is taken. Example: Reading of a hydrometer standardized at 20°/4°C. is 1.550; to convert to value standardized at 20°/20°C., add .0027, making 1.5527.

Specific Gravity 60°/60°F. or 15.56°/15.56°C.	Corrections to be Added				
	15°/4°C.	20°/4°C.	20°/20°C.	17½°/17½°C.	25°/25°C.
0.650	—0.0006	—0.0007	+0.0005	+0.0002	+0.0012
0.675	—0.0006	—0.0007	+0.0005	+0.0002	+0.0012
0.700	—0.0007	—0.0008	+0.0005	+0.0002	+0.0012
0.750	—0.0007	—0.0008	+0.0005	+0.0002	+0.0013
0.800	—0.0007	—0.0008	+0.0005	+0.0002	+0.0013
0.825	—0.0008	—0.0009	+0.0006	+0.0002	+0.0014
0.875	—0.0008	—0.0009	+0.0006	+0.0002	+0.0015
0.900	—0.0009	—0.0010	+0.0006	+0.0002	+0.0016
0.925	—0.0009	—0.0010	+0.0007	+0.0002	+0.0016
1.000	—0.0009	—0.0011	+0.0007	+0.0003	+0.0017
1.050	—0.0010	—0.0011	+0.0007	+0.0003	+0.0018
1.075	—0.0010	—0.0011	+0.0007	+0.0003	+0.0019
1.100	—0.0010	—0.0012	+0.0008	+0.0003	+0.0019
1.150	—0.0011	—0.0012	+0.0008	+0.0003	+0.0020
1.200	—0.0011	—0.0013	+0.0008	+0.0003	+0.0021
1.225	—0.0012	—0.0013	+0.0009	+0.0003	+0.0021
1.250	—0.0012	—0.0013	+0.0009	+0.0004	+0.0022
1.300	—0.0012	—0.0014	+0.0009	+0.0004	+0.0023
1.325	—0.0012	—0.0014	+0.0009	+0.0004	+0.0024
1.350	—0.0013	—0.0014	+0.0010	+0.0004	+0.0024

Conversion of Specific Gravity Hydrometer Readings to Various Temperatures of Standardization—Continued

Specific Gravity 60°/60°F. or 15.56°/15.56°C.	Corrections to be Added				
	15°/4°C.	20°/4°C.	20°/20°C.	17½°/17½°C.	25°/25°C.
1.375	—0.0013	—0.0015	+0.0010	+0.0004	+0.0024
1.400	—0.0013	—0.0015	+0.0010	+0.0004	+0.0025
1.450	—0.0014	—0.0015	+0.0010	+0.0004	+0.0025
1.475	—0.0014	—0.0016	+0.0010	+0.0004	+0.0026
1.500	—0.0014	—0.0016	+0.0011	+0.0004	+0.0026
1.550	—0.0015	—0.0016	+0.0011	+0.0004	+0.0027
1.575	—0.0015	—0.0017	+0.0011	+0.0004	+0.0027
1.600	—0.0015	—0.0017	+0.0011	+0.0004	+0.0028
1.625	—0.0015	—0.0017	+0.0011	+0.0005	+0.0028
1.650	—0.0016	—0.0017	+0.0012	+0.0005	+0.0029
1.700	—0.0016	—0.0018	+0.0012	+0.0005	+0.0030
1.725	—0.0016	—0.0018	+0.0012	+0.0005	+0.0031
1.775	—0.0017	—0.0019	+0.0012	+0.0005	+0.0031
1.800	—0.0017	—0.0019	+0.0013	+0.0005	+0.0032
1.850	—0.0017	—0.0019	+0.0013	+0.0005	+0.0032
1.900	—0.0018	—0.0020	+0.0013	+0.0005	+0.0033
1.925	—0.0018	—0.0020	+0.0014	+0.0005	+0.0033
1.950	—0.0018	—0.0021	+0.0014	+0.0006	+0.0034
2.000	—0.0019	—0.0021	+0.0014	+0.0006	+0.0035

*60°/60° F. means readings taken at 60° F. compared to water at 60°F. as 1.0000.

Correction Tables for Mercurial Barometer, and Other Mercury-Column Readings

The following tables have been compiled to meet the demand for accurate, but simple correction tables for the use of the engineer and physicist, who have occasion to make accurate measurements with the mercurial barometer or other mercury column.

They are prepared in such form as to eliminate all unnecessary work in applying these corrections. Although they are carried out to the third decimal place in accordance with standard practice, attention is called to the fact that the experience of the U. S. Bureau of Standards indicates that it is not as a rule possible to secure a greater accuracy than .01 inch in reading a mercurial barometer or other mercury column.

To determine the readings of a mercury barometer or other mercury column (such as a vacuum gauge) under so-called "standard conditions," the following corrections should, in general, be applied to the observed readings.

1 For temperature of mercury.
2 For temperature of scale.
3 For capillarity.
4 To reduce to standard value of gravity.
  (a) Altitude term.
  (b) Latitude term.

Corrections for instrumental errors are so small in a well-made instrument that they usually can be neglected.

A: Correction for Relative Expansion of Mercury and Brass Scale, the Standard Being 29.92″.

Temp. in degrees F.	Mercury Column Reading in Inches												
	19	20	21	22	23	24	25	26	27	28	29	30	31
30	.002	.002	.003	.003	.003	.003	.003	.003	.003	.003	.004	.004	.004
32	.006	.006	.006	.007	.007	.007	.008	.008	.008	.009	.009	.009	.009
34	.009	.010	.010	.011	.011	.012	.012	.013	.013	.014	.014	.015	.015
36	.013	.013	.014	.015	.015	.016	.017	.017	.018	.019	.019	.020	.021
38	.016	.017	.018	.019	.020	.020	.021	.022	.023	.024	.025	.026	.026
40	.020	.021	.022	.023	.024	.025	.026	.027	.028	.029	.030	.031	.032
42	.023	.024	.025	.027	.028	.029	.030	.032	.033	.034	.035	.036	.038
44	.026	.028	.029	.031	.032	.033	.035	.036	.038	.039	.040	.042	.043
46	.030	.031	.033	.035	.036	.038	.039	.041	.043	.044	.046	.047	.049
48	.033	.035	.037	.039	.040	.042	.044	.046	.047	.049	.051	.053	.054
50	.037	.039	.041	.043	.045	.046	.048	.050	.052	.054	.056	.058	.060
52	.040	.042	.044	.047	.049	.051	.053	.055	.057	.059	.061	.064	.066
54	.044	.046	.048	.051	.053	.055	.057	.060	.062	.064	.067	.069	.071
56	.047	.050	.052	.055	.057	.060	.062	.064	.067	.069	.072	.074	.077
58	.051	.053	.056	.059	.061	.064	.066	.069	.072	.074	.077	.080	.082
60	.054	.057	.060	.062	.065	.068	.071	.074	.077	.080	.082	.085	.088
62	.057	.060	.063	.066	.069	.073	.076	.079	.082	.085	.088	.091	.094
64	.061	.064	.067	.070	.074	.077	.080	.083	.086	.090	.093	.096	.099
66	.064	.068	.071	.074	.078	.081	.085	.088	.091	.095	.098	.101	.105
68	.068	.071	.075	.078	.082	.085	.089	.093	.096	.100	.103	.107	.110
70	.071	.075	.079	.082	.086	.090	.094	.097	.101	.105	.109	.112	.116
72	.075	.078	.082	.086	.090	.094	.098	.102	.106	.110	.114	.118	.122
74	.078	.082	.086	.090	.094	.098	.103	.107	.111	.115	.119	.123	.127
76	.081	.086	.090	.094	.098	.103	.107	.111	.116	.120	.124	.128	.133
78	.085	.089	.094	.098	.103	.107	.112	.116	.120	.125	.129	.134	.138
80	.088	.093	.097	.102	.107	.111	.116	.121	.125	.130	.135	.139	.144
82	.092	.096	.101	.106	.111	.116	.121	.125	.130	.135	.140	.145	.149
84	.095	.100	.105	.110	.115	.120	.125	.130	.135	.140	.145	.150	.155
86	.098	.104	.109	.114	.119	.124	.130	.135	.140	.145	.150	.155	.161
88	.102	.107	.113	.118	.123	.129	.134	.139	.145	.150	.155	.161	.166
90	.105	.111	.116	.122	.127	.133	.138	.144	.150	.155	.161	.166	.172
92	.109	.114	.120	.126	.132	.137	.143	.149	.154	.160	.166	.172	.177
94	.112	.118	.124	.130	.136	.142	.147	.153	.159	.165	.171	.177	.183
96	.115	.122	.128	.134	.140	.146	.152	.158	.164	.170	.176	.182	.188
98	.119	.125	.131	.138	.144	.150	.156	.163	.169	.175	.181	.188	.194
100	.122	.129	.135	.142	.148	.154	.161	.167	.174	.180	.187	.193	.200

Correction Tables for Mercurial Barometer and other Mercury-Column Readings—Continued

Corrections for temperature of scale and mercury, usually are combined into a single table; (A). This table gives corrections which are to be *subtracted from* the *observed readings* of a mercurial column having a brass scale, to eliminate effect of temperature change on both mercury and scale. The use of this table gives barometer readings corrected to mercury-column temperature of 32°F., and scale temperature of 62°F., which are the standard temperature conditions when English measures are used. Under these conditions the standard barometric height is 29.92″.

B: Correction for Relative Expansion of Mercury and Brass Scale, the Standard Being 30.00″.

Difference in Temp. from 58°F.	Mercury Column Reading in Inches												
	19	20	21	22	23	24	25	26	27	28	29	30	31
2	.003	.004	.004	.004	.004	.004	.005	.005	.005	.005	.005	.005	.006
4	.007	.007	.008	.008	.008	.009	.009	.009	.010	.010	.011	.011	.011
6	.010	.011	.011	.012	.013	.013	.014	.014	.015	.015	.016	.016	.017
8	.014	.015	.015	.016	.017	.017	.018	.019	.020	.020	.021	.022	.023
10	.017	.018	.019	.020	.021	.022	.023	.024	.025	.025	.026	.027	.028
12	.021	.022	.023	.024	.025	.026	.027	.028	.029	.031	.032	.033	.034
14	.024	.025	.027	.028	.029	.031	.032	.033	.034	.036	.037	.038	.039
16	.028	.029	.031	.032	.033	.035	.036	.038	.039	.041	.042	.044	.045
18	.031	.032	.034	.036	.038	.039	.041	.042	.044	.046	.047	.049	.051
20	.035	.036	.038	.040	.042	.044	.045	.047	.049	.051	.053	.054	.056
22	.038	.040	.042	.044	.046	.048	.050	.052	.054	.056	.058	.060	.062
24	.041	.044	.046	.048	.050	.052	.054	.057	.059	.061	.063	.065	.068
26	.045	.047	.050	.052	.054	.057	.059	.061	.064	.066	.069	.071	.073
28	.048	.051	.053	.056	.058	.061	.064	.066	.069	.071	.074	.076	.079
30	.052	.054	.057	.060	.063	.065	.068	.071	.074	.076	.079	.082	.084
32	.055	.058	.061	.064	.067	.070	.073	.076	.078	.081	.084	.087	.090
34	.059	.062	.065	.068	.071	.074	.077	.080	.083	.086	.090	.093	.096
36	.062	.065	.069	.072	.075	.078	.082	.085	.088	.092	.095	.098	.101
38	.066	.069	.072	.076	.079	.083	.086	.090	.093	.097	.100	.104	.107
40	.069	.073	.076	.080	.084	.087	.091	.094	.098	.102	.106	.109	.113
42	.072	.076	.080	.084	.088	.092	.095	.099	.103	.107	.111	.114	.118
44	.076	.080	.084	.088	.092	.096	.100	.104	.108	.112	.116	.120	.124
46	.079	.084	.088	.092	.096	.100	.104	.109	.113	.117	.121	.125	.129
48	.083	.087	.092	.096	.100	.105	.109	.113	.118	.122	.127	.131	.135
50	.086	.091	.095	.100	.104	.109	.114	.118	.123	.127	.132	.136	.141

Correction Tables for Mercurial Barometer and other Mercury-Column Readings—Continued

(B) gives corrections which are to be applied to the *observed readings* of a mercurial column having a brass scale, to eliminate the effect of temperature change on both mercury and scale, when it is desired to correct to a standard barometric height of 30.00″. The standard barometric height of 29.92″ as defined under (A) becomes a height of 30.00″ when mercury column and brass scale are both at a temperature of 58.1° F. (practically 58°F.). The corrections in (B) are to be *added to* observed readings for temperatures *below* 58°F., and *subtracted from* them for temperatures *above this* point.

C: Correction for Capillarity.

Diameter of Mercury Column in Inches	Height of Meniscus in Inches							
	.01	.02	.03	.04	.05	.06	.07	.08
.15	.024	.047	.069	.092	.116	....	....	....
.20	.011	.022	.033	.045	.059	.078	....	....
.25	.006	.012	.019	.028	.037	.047	.059	....
.30	.004	.008	.013	.018	.023	.029	.035	.042
.35	....	.005	.008	.012	.015	.018	.022	.026
.40	....	.004	.006	.008	.010	.012	.014	.016
.45	....	....	.003	.005	.007	.008	.010	.012
.50	....	....	.002	.004	.005	.006	.006	.007
.55	....	....	.001	.002	.003	.004	.005	.005

The correction from (C) is to be *added to* the observed reading of the mercury column, if it is to be made at all. (See discussion in the next paragraph.) The height of the meniscus may be obtained by setting the vernier for the top of the meniscus, and again for the bottom, reading the position of the vernier on the scale for each. The difference is the required height.

The manufacturer adjusts the scale to correct for capillarity at one point on the scale. This correction may change with time, also with location of the mercury surface. But the change is very slight in a barometer as long as mercury and tube remain clean and bright. The change in a mercury vacuum gauge, however, may be appreciable, see (C) for this correction.

Correction Tables for Mercurial Barometer and other Mercury-Column Readings—Continued

D: Reduction to Standard Gravity as Affected by Altitude.

Altitude in Feet	Mercury Column Reading in Inches												
	19	20	21	22	23	24	25	26	27	28	29	30	31
0	..	..	..	..	..	..	..	..	.000	.000	.000	.000	.000
500	..	..	..	..	..	..	..	..	.001	.001	.001	.001	.001
1000	..	..	..	..	..	..	..	..	.002	.002	.002	.002	.002
1500	..	..	..	..	..	..	..	.002	.002	.003	.003	.003	..
2000	..	..	..	..	..	..	..	.003	.003	.003	.003	.004	..
2500	..	..	..	..	..	..	.004	.004	.004	.004	.004	..	..
3000	..	..	..	..	..	..	.004	.005	.005	.005	.005	..	..
3500	..	..	..	..	..	.005	.005	.005	.006	.006	..	..	..
4000	..	..	..	..	..	.006	.006	.006	.006	.007	..	..	..
4500	..	..	..	..	.006	.006	.007	.007	.007	..	..	..	..
5000	..	..	..	..	.007	.007	.007	.008	.008	..	..	..	..
5500	..	..	..	.007	.008	.008	.008	.009	..	..	..	..	..
6000	..	..	..	.008	.008	.009	.009	.009	..	..	..	..	..
6500	..	..	.008	.009	.009	.009	.010	..	..	..	..	..	..
7000	..	..	.009	.009	.010	.010	.010	..	..	..	..	..	..
7500	..	.009	.009	.010	.010	.011	..	..	..	..	..	..	..
8000	..	.010	.010	.011	.011	.011	..	..	..	..	..	..	..
8500	.010	.010	.011	.011	.012	..	..	..	..	..	..	..	..
9000	.010	.011	.011	.012	.012	..	..	..	..	..	..	..	..
9500	.011	.011	.012	.012	..	..	..	..	..	..	..	..	..
10000	.011	.012	.013	.013	..	..	..	..	..	..	..	..	..

(D) gives the correction for variations in gravity due to altitude, which is to be *subtracted from* the observed reading.

It is to be noted that (D) refers to the *very slight* reduction in weight of any body (a mercury column, in this case) as it is raised above sea level. It does not refer to the rapid diminution in air pressure with increasing altitude. Therefore this correction *does not give the "sea level" reading.*

Correction Tables for Mercurial Barometer and other Mercury-Column Readings—Continued

E: Reduction to Standard Gravity as Affected by Latitude.

Latitude in Degrees	Mercury Column Reading in Inches											
	19	20	21	22	23	24	25	26	27	28	29	30
0° & 90°	.049	.052	.054	.057	.060	.062	.065	.067	.070	.073	.075	.078
5° & 85°	.048	.051	.054	.056	.059	.061	.064	.066	.069	.071	.074	.077
10° & 80°	.046	.049	.051	.054	.056	.058	.061	.063	.066	.068	.071	.073
15° & 75°	.043	.045	.047	.049	.052	.054	.056	.058	.061	.063	.065	.067
20° & 70°	.038	.040	.042	.044	.046	.048	.050	.052	.054	.056	.058	.060
25° & 65°	.032	.033	.035	.037	.038	.040	.042	.043	.045	.047	.048	.050
30° & 60°	.025	.026	.027	.028	.030	.031	.032	.034	.035	.036	.038	.039
35° & 55°	.017	.018	.019	.019	.020	.021	.022	.023	.024	.025	.026	.027
40° & 50°	.009	.009	.009	.010	.010	.011	.011	.012	.012	.013	.013	.013
45° & 45°	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

(E) gives the correction to be applied to a mercury column reading for variation in gravity due to latitude. For latitudes *above* 45° the values are to be *added* to observed readings; for latitudes *below* 45°, they are to be *subtracted.*

All of these correction tables are determined arbitrarily on the basis of certain assumptions. The values given herein are those which have been adopted as standard, as noted below.

(A), (D), and (E) are compiled from those of the U. S. Weather Bureau (Weather Bureau, Instrument Division, Circular F., Fifth Edition); (C), from "Smithsonian Physical Tables" (published by the Smithsonian Institution, Washington, D. C.); the values in (B) are calculated from the values of the co-efficients of expansion of mercury and of brass as given in the above mentioned circular F. page 27.

Recent work of the U. S. Bureau of Standards shows that commercial mercury barometers can not be depended upon closer than .01″, consequently the final corrected value of a mercury column reading is always in question by this amount. When it becomes necessary to make a correction for capillarity, the uncertainty in the final result is somewhat greater. Corrections in the tables are given to the third decimal place, however, to conform to established custom.

Correction Tables for Mercurial Barometer and other Mercury-Column Readings—Continued

Those who wish to go into the theoretical considerations involved will find a good discussion in the "Smithsonian Meteorological Tables" Fourth Edition; (published by the Smithsonian Institution, Washington, D. C.); also in "A Dictionary of Applied Physics," Vol. III., edited by Sir Richard Glazebrook (published by MacMillan Company).

The "correction to sea level" is complicated and involves serious difficulties; consequently it is not included here. If it is desired, it may be found in Smithsonian Meteorological Tables, Third Edition.

The following examples will illustrate the method of correcting readings:

EXAMPLE 1: To Correct to Standard Barometer of 29.92″.

Observed barometer reading	28.472″
Reading of attached thermometer	80.5°F.
Correction for temperature (A)	−.134″
Altitude	1525 ft.
Correction for altitude (D)	−.003″
Latitude	32° 40′N.
Correction for latitude (E)	−.031″
Total correction	−.168″
Corrected barometer reading	28.304″

EXAMPLE II: To correct to Standard Barometer of 30.00″.

Observed barometer reading	28.156″
Reading of attached thermometer.	44.5°F.
Deviation from temperature of 58°F.	13.5° F.
Correction for temperature (B)	+.035″
Altitude	1600 ft.
Correction for altitude (D)	−.003″
Latitude	26° 30′N.
Correction for latitude (E)	−.044″
Total correction	−.012″
Corrected barometer reading	28.144″

Correction Tables for Mercurial Barometer and other Mercury-Column Readings—Continued

EXAMPLE III: If a capillary correction (see (C) and explanatory paragraphs following) is to be made it is done as follows:

Diameter of mercury column	.25″
Reading, top of meniscus	28.472″
Reading bottom of meniscus	28.415″
Height of meniscus	.057″
Correction for capillarity (C)	.044″

which is to be added to the observed reading at top of the meniscus.

Relative Humidity Table

This table is an abridged arrangement from the complete table by C. F. Marvin, Chief of the United States Weather Bureau, for dry bulb thermometer readings up to 140°F. For dry bulb readings above 140°F. it is compiled from data furnished by the Bureau of Standards and is an extrapolation from figures obtained by actual experiments at lower temperatures.

The values given in this table are correct for air velocities of 600 ft. per minute and over, and for barometeric pressure of 29.92 inches. The temperature readings are in degrees Fahrenheit, humidity in per cent.

The error introduced by a change in barometric pressure is a variable. For a barometric pressure of 25.00 inches, at normal air temperature, this table would be in error in the humidity reading of from about 1% at 90% humidity to 5% at 20% humidity, in both cases being low. This error diminishes slightly with rise and increases slightly with fall of air temperatures.

The error caused by reduction in air velocity below 600 ft. per minute is very small, down to velocities of approximately 100 ft. per minute. For velocities lower than 100 ft. per minute the error is inappreciable at high air temperatures and high humidity. At lower temperatures, however, a decrease in any one or more of the following factors may cause considerable error; air velocity, air temperature and percent humidity.

A relative idea of the approximate error may be obtained from the following: in still air at a dry bulb temperature of 90°F. and 40% humidity, this table is in error by about 3% humidity; at a dry bulb temperature of 60°F. and 80% humidity, by about 3% humidity; at a dry bulb temperature of 55°F. at 20% humidity, there would be an error of about 22% humidity. In all of the above cases the table reads too high.

Directions for the Use of Table

To find the relative humidity for a reading of the dry bulb at 49°F., and the wet bulb at 39° F., subtract the wet bulb reading (39°) from the dry bulb reading (49°) which gives a difference of 10°. Follow down the column headed 10° and read across the table from the dry bulb reading 49°. The two lines will intersect at 36, which indicates a relative humidity of 36%.

Relative Humidity Tables—Continued

READINGS OF "DRY-BULB" THERMO-METER	DIFFERENCE BETWEEN READINGS OF "WET-BULB" AND "DRY-BULB" THERMOMETERS							
	1°	2°	3°	4°	5°	6°	7°	8°
20°	85%	70%	55%	40%	26%	12%		
21°	85	71	56	42	28	15	1%	
22°	86	71	58	44	31	17	4	
23°	86	72	59	46	33	20	7	
24°	87	73	60	47	35	22	10	
25°	87	74	62	49	37	25	13	1%
26°	87	75	63	51	39	27	16	4
27°	88	76	64	52	41	29	18	7
28°	88	76	65	54	43	32	21	10
29°	88	77	66	55	44	34	23	13
30°	89	78	67	56	46	36	26	16
31°	89	78	68	58	47	37	28	18
32°	89	79	69	59	49	39	30	20
33°	90	80	70	60	51	41	32	23
34°	90	81	71	62	52	43	34	25
35°	91	81	72	63	54	45	36	27
36°	91	82	73	64	55	46	38	29
37°	91	83	74	65	57	48	40	31
38°	91	83	75	66	58	50	42	33
39°	92	83	75	67	59	51	43	35
40°	92	83	75	68	60	52	45	37
41°	92	84	76	69	61	54	46	39
42°	92	85	77	69	62	55	47	40
43°	92	85	77	70	63	55	48	42
44°	93	85	78	71	63	56	49	43
45°	93	86	78	71	64	57	51	44
46°	93	86	79	72	65	58	52	45
47°	93	86	79	72	66	59	53	46
48°	93	86	79	73	66	60	54	47
49°	93	86	80	73	67	61	54	48

Relative Humidity Tables—Continued

READINGS OF "DRY-BULB" THERMO-METER	DIFFERENCE BETWEEN READINGS OF "WET-BULB" AND "DRY-BULB" THERMOMETERS							
	9°	10°	11°	12°	13°	14°	15°	16°
20°								
21°								
22°								
23°								
24°								
25°								
26°								
27°								
28°								
29°	3%							
30°	6							
31°	8							
32°	11	4%						
33°	14	5						
34°	16	8						
35°	19	10	2%					
36°	21	13	5					
37°	23	15	7					
38°	25	17	10	2%				
39°	27	20	12	5				
40°	29	22	15	7				
41°	31	24	17	10	3%			
42°	33	26	19	12	5			
43°	35	28	21	14	8	1%		
44°	36	30	23	16	10	4		
45°	38	31	25	18	12	6		
46°	39	32	26	20	14	8	2%	
47°	40	34	28	22	16	10	5	
48°	41	35	29	23	18	12	7	1%
49°	42	36	31	25	19	14	9	3

Relative Humidity Tables—Continued

READINGS OF "DRY BULB" THERMO-METER	DIFFERENCE BETWEEN READINGS OF "WET-BULB" AND "DRY-BULB" THERMOMETERS									
	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°
50°	93	87	80	74	67	61	55	49	43	38
51°	94	87	81	75	68	62	56	50	45	39
52°	94	87	81	75	69	63	57	51	46	40
53°	94	87	81	75	69	63	58	52	47	41
54°	94	88	82	76	70	64	59	53	48	42
55°	94	88	82	76	70	65	59	54	49	43
56°	94	88	82	76	71	65	60	55	50	44
57°	94	88	82	77	71	66	61	55	50	45
58°	94	88	83	77	72	66	61	56	51	46
59°	94	89	83	78	72	67	62	57	52	47
60°	94	89	83	78	73	68	63	58	53	48
61°	94	89	84	78	73	68	63	58	54	49
62°	94	89	84	79	74	69	64	59	54	50
63°	95	89	84	79	74	69	64	60	55	50
64°	95	90	84	79	74	70	65	60	56	51
65°	95	90	85	80	75	70	66	61	56	52
66°	95	90	85	80	75	71	66	61	57	53
67°	95	90	85	80	75	71	66	62	58	53
68°	95	90	85	80	76	71	67	62	58	54
69°	95	90	85	81	76	72	67	63	59	55
70°	95	90	86	81	77	72	68	64	59	55
71°	95	90	86	81	77	72	68	64	60	56
72°	95	91	86	82	77	73	69	65	61	57
73°	95	91	86	82	78	73	69	65	61	57
74°	95	91	86	82	78	74	69	65	61	58
75°	96	91	86	82	78	74	70	66	62	58
76°	96	91	87	82	78	74	70	66	62	59
77°	96	91	87	83	79	74	71	67	63	59
78°	96	91	87	83	79	75	71	67	63	60
79°	96	91	87	83	79	75	71	68	64	60

Relative Humidity Tables—Continued

READINGS OF "DRY BULB" THERMOMETER	DIFFERENCE BETWEEN READINGS OF "WET-BULB" AND "DRY-BULB" THERMOMETERS									
	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°
50°	32	27	21	16	10	5				
51°	34	28	23	17	12	7	2			
52°	35	29	24	19	14	9	4			
53°	36	31	26	20	16	10	6	1		
54°	37	32	27	22	17	12	8	3		
55°	38	33	28	23	19	14	9	5		
56°	39	34	30	25	20	16	11	7	2	
57°	40	35	31	26	22	17	13	8	4	
58°	41	37	32	27	23	18	14	10	6	1
59°	42	38	33	29	24	20	16	11	7	3
60°	43	39	34	30	26	21	17	13	9	5
61°	44	40	35	31	27	22	18	14	10	7
62°	45	41	36	32	28	24	20	16	12	8
63°	46	42	37	33	29	25	21	17	13	10
64°	47	43	38	34	30	26	22	18	15	11
65°	48	44	39	35	31	27	24	20	16	12
66°	48	44	40	36	32	29	25	21	17	14
67°	49	45	41	37	33	30	26	22	19	15
68°	50	46	42	38	34	31	27	23	20	16
69°	51	47	43	39	35	32	28	24	21	18
70°	51	48	44	40	36	33	29	25	22	19
71°	52	48	45	41	37	33	30	27	23	20
72°	53	49	45	42	38	34	31	28	24	21
73°	53	50	46	42	39	35	32	29	25	22
74°	54	50	47	43	39	36	33	29	26	23
75°	54	51	47	44	40	37	34	30	27	24
76°	55	51	48	44	41	38	34	31	28	25
77°	56	52	48	45	42	39	35	32	29	26
78°	56	53	49	46	43	39	36	33	30	27
79°	57	53	50	46	43	40	37	34	31	28

Relative Humidity Tables—Continued

READINGS OF "DRY-BULB" THERMOMETER	DIFFERENCE BETWEEN READINGS OF "WET-BULB" AND "DRY-BULB" THERMOMETERS									
	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°
50°										
51°										
52°										
53°										
54°										
55°										
56°										
57°										
58°										
59°										
60°	1									
61°	3									
62°	4	1								
63°	6	2								
64°	7	4								
65°	9	5	2							
66°	10	7	3							
67°	12	8	5	2						
68°	13	10	6	3						
69°	14	11	8	5	1					
70°	15	12	9	6	3					
71°	17	13	10	7	4	1				
72°	18	15	12	9	6	3				
73°	19	16	13	10	7	4	1			
74°	20	17	14	11	8	5	3			
75°	21	18	15	12	9	7	4	1		
76°	22	19	16	13	11	8	5	3		
77°	23	20	17	14	12	9	6	4	1	
78°	24	21	18	16	13	10	8	5	3	
79°	25	22	19	17	14	11	9	6	4	1

Relative Humidity Tables—Continued

READINGS OF "DRY-BULB" THERMO-METER	DIFFERENCE BETWEEN READINGS OF "WET-BULB" AND "DRY-BULB" THERMOMETERS																
	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°	16°	17°
80°	96	91	87	83	79	75	72	68	64	61	57	54	50	47	44	41	38
82°	96	92	88	84	80	76	72	69	65	61	58	55	51	48	45	42	39
84°	96	92	88	84	80	76	73	69	66	62	59	56	52	49	46	43	40
86°	96	92	88	84	81	77	73	70	66	63	60	57	53	50	47	44	42
88°	96	92	88	85	81	77	74	70	67	64	61	57	54	51	48	46	43
90°	96	92	89	85	81	78	74	71	68	65	61	58	55	52	49	47	44
92°	96	92	89	85	82	78	75	72	68	65	62	59	56	53	50	48	45
94°	96	93	89	85	82	79	75	72	69	66	63	60	57	54	51	49	46
96°	96	93	89	86	82	79	76	73	69	66	63	61	58	55	52	50	47
98°	96	93	89	86	82	79	76	73	70	67	64	61	58	55	53	50	48
100°	96	93	89	86	83	80	77	73	70	68	65	62	59	56	54	51	49
102°	96	93	90	86	83	80	77	74	71	68	65	62	60	57	55	52	49
104°	97	93	90	87	83	80	77	74	71	69	66	63	60	58	55	53	50
106°	97	93	90	87	84	81	78	75	72	69	66	64	61	58	56	53	51
108°	97	93	90	87	84	81	78	75	72	70	67	64	62	59	57	54	52
110°	97	93	90	87	84	81	78	75	73	70	67	65	62	60	57	55	52
112°	97	94	90	87	84	81	79	76	73	70	68	65	63	60	58	55	53
114°	97	94	91	88	85	82	79	76	74	71	68	66	63	61	58	56	54
116°	97	94	91	88	85	82	79	76	74	71	69	66	64	61	59	57	54
118°	97	94	91	88	85	82	79	77	74	72	69	67	64	62	59	57	55
120°	97	94	91	88	85	82	80	77	74	72	69	67	65	62	60	58	55
122°	97	94	91	88	85	83	80	77	75	72	70	67	65	63	60	58	56
124°	97	94	91	88	85	83	80	78	75	73	70	68	65	63	61	59	57
126°	97	94	91	88	86	83	80	78	75	73	70	68	66	64	61	59	57
128°	97	94	91	89	86	83	81	78	76	73	71	68	66	64	62	60	58
130°	97	94	91	89	86	83	81	78	76	73	71	69	67	64	62	60	58
132°	97	94	92	89	86	84	81	79	76	74	71	69	67	65	63	61	58
134°	97	94	92	89	86	84	81	79	76	74	72	69	67	65	63	61	59
136°	97	94	92	89	86	84	81	79	77	74	72	70	68	65	63	61	59
138°	97	94	92	89	87	84	82	79	77	75	72	70	68	66	64	62	60

Relative Humidity Tables—Continued

READINGS OF "DRY-BULB" THERMO-METER	DIFFERENCE BETWEEN READINGS OF "WET-BULB" AND "DRY-BULB" THERMOMETERS																
	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°	31°	32°	33°	34°
80°	35	32	29	26	23	20	18	15	12	10	7	5	3				
82°	36	33	30	28	25	22	20	17	14	12	10	7	5	2			
84°	37	35	32	29	26	24	21	19	16	14	12	9	7	5	3		
86°	39	36	33	31	28	26	23	21	18	16	14	11	9	7	5	3	1
88°	40	37	35	32	30	27	25	22	20	18	15	13	11	9	7	5	3
90°	41	39	36	34	31	29	26	24	22	19	17	15	13	11	9	7	5
92°	42	40	37	35	32	30	28	25	23	21	19	17	15	13	11	9	7
94°	43	41	38	36	33	31	29	27	24	22	20	18	16	14	12	10	9
96°	44	42	39	37	35	32	30	28	26	24	22	20	18	16	14	12	10
98°	45	43	40	38	36	34	32	29	27	25	23	21	19	17	15	14	12
100°	46	44	41	39	37	35	33	30	28	26	24	22	21	19	17	15	13
102°	47	45	42	40	38	36	34	32	30	28	26	24	22	20	18	16	15
104°	48	46	43	41	39	37	35	33	31	29	27	25	23	21	20	18	16
106°	49	46	44	42	40	38	36	34	32	30	28	26	24	23	21	19	17
108°	49	47	45	43	41	39	37	35	33	31	29	27	25	24	22	20	19
110°	50	48	46	44	42	40	38	36	34	32	30	28	26	25	23	21	20
112°	51	49	47	44	42	40	38	36	35	33	31	29	27	26	24	23	21
114°	52	49	47	45	43	41	39	37	35	34	32	30	28	27	25	24	22
116°	52	50	48	46	44	42	40	38	36	34	33	31	29	28	26	25	23
118°	53	51	49	47	45	43	41	39	37	35	34	32	30	29	27	25	24
120°	53	51	49	47	45	43	41	40	38	36	34	33	31	29	28	26	25
122°	54	52	50	48	46	44	42	40	39	37	35	34	32	30	29	27	26
124°	54	52	50	48	47	45	43	41	39	38	36	34	33	31	30	28	27
126°	55	53	51	49	47	45	44	42	40	38	37	35	33	32	30	29	27
128°	56	54	52	50	48	46	44	42	41	39	37	36	34	33	31	30	28
130°	56	54	52	50	48	47	45	43	41	40	38	37	35	33	32	30	29
132°	56	55	53	51	49	47	45	44	42	40	39	37	36	34	33	31	30
134°	57	55	53	51	49	48	46	44	43	41	39	38	36	35	33	32	30
136°	57	55	54	52	50	48	46	45	43	41	40	38	37	35	34	33	31
138°	58	56	54	52	50	49	47	45	44	42	40	39	37	36	34	33	32

Relative Humidity Tables—Continued

READINGS OF "DRY-BULB" THERMOMETER	DIFFERENCE BETWEEN READINGS OF "WET-BULB" AND "DRY-BULB" THERMOMETERS															
	35°	36°	37°	38°	39°	40°	41°	42°	43°	44°	45°	46°	47°	48°	49°	50°
80°																
82°																
84°																
86°																
88°	1															
90°	3	1														
92°	5	3	1													
94°	7	5	3	1												
96°	8	7	5	3	2											
98°	10	8	7	5	3	2										
100°	12	10	8	7	5	4	2	1								
102°	13	11	10	8	7	5	4	2	1							
104°	14	13	12	10	8	7	5	4	2	1						
106°	16	14	13	11	10	8	7	5	4	3	1					
108°	17	16	14	12	11	10	8	7	5	4	3	2				
110°	18	17	15	14	12	11	10	8	7	6	4	3	2	1		
112°	19	18	16	15	14	12	11	9	8	7	6	4	3	2	1	
114°	20	19	18	16	15	13	12	11	9	8	7	6	5	3	2	1
116°	22	20	19	17	16	14	13	12	11	9	8	7	6	5	4	2
118°	23	21	20	18	17	16	14	13	12	11	9	8	7	6	5	4
120°	23	22	21	19	18	17	15	14	13	12	10	9	8	7	6	5
122°	24	23	22	20	19	18	16	15	14	13	11	10	9	8	7	6
124°	25	24	22	21	20	18	17	16	15	14	12	11	10	9	8	7
126°	26	25	23	22	21	19	18	17	16	15	13	12	11	10	9	8
128°	27	25	24	23	22	20	19	18	17	16	14	13	12	11	10	9
130°	28	26	25	24	22	21	20	19	18	16	15	14	13	12	11	10
132°	28	26	25	24	22	21	21	20	19	17	16	15	14	13	12	11
134°	29	27	26	25	24	22	21	20	19	18	17	16	15	14	13	12
136°	30	28	27	26	25	23	22	21	20	19	18	17	16	15	14	13
138°	30	29	28	27	25	24	23	22	21	20	19	17	16	15	14	14

Relative Humidity Tables—Continued

READINGS OF "DRY-BULB" THERMOMETER	DIFFERENCE BETWEEN READINGS OF "WET-BULB" AND "DRY-BULB" THERMOMETERS															
	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°	16°	17°
140°	97	95	92	89	87	84	82	79	77	75	73	70	68	66	64	62	60
142°	97	95	92	90	87	84	82	80	78	75	73	71	69	67	65	63	60
144°	97	95	93	90	87	84	82	80	78	75	73	71	69	67	65	63	61
146°	98	95	93	90	87	85	82	80	78	76	73	71	69	67	65	63	61
148°	98	95	93	90	87	85	82	80	78	76	73	71	70	68	65	64	61
150°	98	95	93	90	87	85	82	80	78	76	73	71	70	68	65	64	62
152°	98	95	93	90	87	85	83	81	79	76	74	72	71	68	66	64	62
154°	98	95	93	90	87	85	83	81	79	76	74	72	71	69	66	65	63
156°	98	95	93	90	88	85	83	81	79	77	74	72	71	69	66	65	63
158°	98	95	93	90	88	85	83	81	79	77	74	72	71	69	66	65	63
160°	98	95	93	90	88	85	83	81	79	77	75	73	71	69	67	65	63
162°	98	95	93	91	88	86	84	82	80	77	75	73	72	70	67	66	64
164°	98	95	93	91	88	86	84	82	80	78	75	73	72	70	67	66	64
166°	98	96	94	91	89	86	84	82	80	78	76	74	72	70	68	66	64
168°	98	96	94	91	89	86	84	82	80	78	76	74	72	70	68	67	65
170°	98	96	94	91	89	86	84	82	80	78	76	74	72	70	69	67	65
172°	98	96	94	92	89	87	85	83	81	79	76	74	73	71	69	67	65
174°	98	96	94	92	89	87	85	83	81	79	76	74	73	71	69	67	66
176°	98	96	94	92	89	87	85	83	81	79	77	75	73	71	69	68	66
178°	98	96	94	92	89	87	85	83	81	79	77	75	73	72	70	68	66
180°	98	96	94	92	89	87	85	83	81	79	77	75	73	72	70	68	66
182°	98	96	94	92	90	87	85	83	81	79	77	76	74	72	70	69	67
184°	98	96	94	92	90	87	85	83	81	79	77	76	74	72	70	69	67
186°	98	96	94	92	90	87	85	83	81	80	78	76	74	73	71	69	67
188°	98	96	94	92	90	87	85	83	82	80	78	76	74	73	71	69	67
190°	98	96	94	92	90	87	85	83	82	80	78	76	74	73	71	69	68
192°	98	96	94	92	90	88	86	84	82	80	78	76	75	73	71	70	68
194°	98	96	94	92	90	88	86	84	82	80	78	76	75	73	71	70	68
196°	98	96	94	92	90	88	86	84	82	80	78	77	75	74	72	70	69
198°	98	96	94	92	90	88	86	84	82	80	78	77	75	74	72	70	69

Relative Humidity Tables—Continued

READINGS OF "DRY-BULB" THERMOMETER	DIFFERENCE BETWEEN READINGS OF "WET-BULB" AND "DRY-BULB" THERMOMETERS																
	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°	31°	32°	33°	34°
140°	58	56	54	53	51	49	47	46	44	42	41	39	38	36	35	34	32
142°	59	57	55	53	52	50	48	46	45	43	42	40	39	37	36	34	33
144°	59	57	55	54	52	50	48	47	45	43	42	40	39	37	36	35	34
146°	59	57	55	54	53	51	49	47	46	44	43	41	40	38	37	36	34
148°	60	58	56	55	53	51	49	48	46	44	43	41	40	39	37	36	35
150°	60	58	56	55	53	52	49	48	46	45	43	42	41	39	38	37	35
152°	60	59	57	56	54	52	50	49	47	45	44	42	41	40	38	37	36
154°	61	59	57	56	54	52	50	49	47	46	44	43	42	40	39	38	36
156°	61	59	57	56	54	53	50	50	47	46	45	43	42	41	39	38	37
158°	61	59	57	57	55	53	51	50	48	47	45	44	43	41	40	39	38
160°	62	60	58	57	55	54	51	50	48	47	46	45	43	42	40	39	38
162°	62	60	58	57	55	54	51	51	49	48	47	45	44	42	41	40	39
164°	62	60	58	58	56	55	52	51	49	48	47	46	44	42	41	40	39
166°	63	61	59	58	56	55	53	52	50	49	48	46	45	43	42	41	40
168°	63	61	59	58	57	55	53	52	50	49	48	47	45	43	42	41	40
170°	63	62	60	59	57	55	53	52	50	49	48	47	45	44	42	41	40
172°	63	62	60	59	58	56	54	53	51	50	49	47	46	44	43	42	41
174°	64	62	61	60	58	56	54	53	51	50	49	48	46	45	43	42	41
176°	64	63	61	60	58	57	55	54	52	51	50	48	47	45	44	43	42
178°	64	63	61	60	58	57	55	54	52	51	50	48	47	46	44	43	42
180°	64	63	61	61	58	57	55	54	52	51	50	49	47	46	44	43	42
182°	65	64	62	61	59	58	56	55	53	52	50	49	48	46	45	44	43
184°	65	64	62	61	59	58	56	55	53	52	50	49	48	47	45	44	43
186°	66	64	63	62	60	59	57	56	54	53	51	49	48	47	46	45	44
188°	66	64	63	62	60	59	57	56	54	53	51	50	48	47	46	45	44
190°	66	64	63	62	60	59	57	56	54	53	51	50	49	47	46	45	44
192°	67	65	63	62	61	60	58	56	55	53	52	50	49	48	47	45	44
194°	67	65	63	63	61	60	58	57	55	54	52	51	50	48	47	46	45
196°	67	66	64	63	61	60	58	57	55	54	53	51	50	48	47	46	45
198°	67	66	64	63	61	60	58	57	55	54	53	51	50	48	48	46	45

Relative Humidity Tables—Continued

READINGS OF "DRY-BULB THERMOMETER	DIFFERENCE BETWEEN READINGS OF "WET-BULB" AND "DRY-BULB" THERMOMETERS																
	35°	36°	37°	38°	39°	40°	41°	42°	43°	44°	45°	46°	47°	48°	49°	50°	
140°	31	30	29	27	26	25	24	23	22	21	20	18	17	16	15	14	
142°	32	31	29	28	27	26	25	24	23	22	21	20	19	18	16	15	
144°	33	31	30	29	28	27	26	25	24	23	22	21	20	19	17	16	
146°	33	32	31	29	28	27	26	25	24	23	22	21	20	19	18	16	
148°	34	33	32	30	29	28	27	26	25	24	23	22	21	20	19	17	
150°	34	33	32	30	29	28	28	27	26	25	24	23	22	21	19	18	
152°	35	34	32	31	30	29	28	27	26	25	24	23	22	21	20	18	
154°	35	34	33	32	31	30	29	28	27	26	25	24	23	22	20	19	
156°	36	35	34	32	31	30	29	28	27	26	25	24	23	22	21	19	
158°	37	35	34	33	32	31	30	29	28	27	26	25	24	23	22	20	
160°	37	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	
162°	38	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	
164°	38	37	36	34	33	32	32	31	30	29	28	27	26	24	23	22	
166°	39	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	
168°	39	38	37	35	34	33	32	31	30	29	28	27	26	25	24	23	
170°	39	38	37	35	34	33	32	31	30	29	28	27	26	25	24	23	
172°	40	39	37	36	35	34	33	32	31	30	29	28	27	26	25	24	
174°	40	39	38	36	35	34	33	32	31	30	29	28	27	26	25	24	
176°	41	40	38	37	36	35	34	33	32	31	30	29	28	27	26	25	
178°	41	40	38	37	36	35	34	33	32	31	30	29	28	27	26	25	
180°	41	40	39	37	36	35	34	33	32	31	30	30	29	28	27	26	
182°	42	41	39	38	37	36	35	34	33	32	31	30	29	28	27	26	
184°	42	41	39	38	37	36	35	34	33	32	31	30	29	28	27	26	
186°	43	42	40	39	37	37	35	34	33	32	31	30	29	28	27	27	
188°	43	42	40	39	38	37	36	35	34	33	32	31	30	29	28	27	
190°	43	42	40	39	38	37	36	35	34	33	32	32	31	30	29	28	
192°	43	42	41	40	39	38	37	36	35	34	33	32	31	30	29	28	
194°	44	42	41	40	39	38	37	36	35	34	33	33	32	31	30	29	
196°	44	43	41	40	39	39	38	37	36	35	34	33	32	31	30	29	
198°	44	43	42	41	40	39	38	37	36	35	34	34	33	32	31	30	

Steam

Under normal atmospheric pressure of 14.7 lbs. per square inch water boils at 212° F. or 100° C. and passes off as steam; the boiling temperature varies however, with changes in pressure.

Steam is perfectly transparent, colorless, dry and invisible. When partially condensed as in contact with the air the mist or spray makes it visible.

Dry steam contains no free moisture. It may be either saturated or superheated.

Wet steam contains free moisture in the form of mist or spray, and has the same temperature as dry saturated steam of the same pressure.

Saturated steam is steam in its normal state. Its temperature is that due to the pressure under which it is formed, that is, its temperature is the same as that of the water from which it is generated and upon which it rests.

Superheated steam is steam at a temperature above that due to its pressure after leaving the water from which it is generated, being further heated from another source.

Water in contact with saturated steam has the same temperature as the steam itself. Water introduced into superheated steam will be vaporized until the steam becomes saturated, and its temperature becomes that due its pressure. Cold water, or water at a lower temperature than that of the steam introduced into saturated steam, will condense some of it, thus lowering both the temperature and pressure of the rest until the temperature again equals that due its pressure.

One volume of water evaporated at normal atmospheric pressure and temperature of 212° F. becomes 1646 volumes of steam, i. e., 1 cu. ft. of water will become 1646 cu. ft. of steam.

One cu. ft. of steam weighs .03732 lbs., and 1 lb. of steam occupies 26.795 cu. ft., at a pressure of 14.7 lbs. per square inch. Temperature 212° F.

One cu. ft. of dry air weighs .08073 lbs., and 1 lb. of dry air occupies 12.387 cu. ft. at a pressure of 14.7 lbs. per square inch. Temperature 0° C.

The latent heat of evaporation of water to steam is 965.7 B. t. u.

The best designed boilers, well set, with good draft and skillful firing, will evaporate from 7 to 10 lbs. of water per pound of first class coal.

Saturated Steam; Vacuum and Temperature*

From 29.8″ of mercury to atmospheric pressure. Referred to a 30″ Barometer, mercury at 58.4° F.

Vacuum in inches	Temperature Deg. F.	Vacuum in inches	Temperature Deg. F.	Vacuum in inches	Temperature Deg. F.
....	....	27.4	110.05	24.0	140.64
29.8	34.42	27.3	111.36	23.0	146.78
29.7	44.91	27.2	112.63	22.0	152.16
29.6	52.60	27.1	113.87	21.0	157.00
29.5	58.77	27.0	115.06	20.0	161.42
29.4	63.86	26.9	116.20	19.0	165.42
29.3	68.33	26.8	117.32	18.0	169.14
29.2	72.27	26.7	118.42	17.0	172.63
29.1	75.84	26.6	119.50	16.0	175.93
29.0	79.07	26.5	120.55	15.0	179.03
28.9	81.97	26.4	121.55	14.0	181.92
28.8	84.61	26.3	122.54	13.0	184.68
28.7	87.10	26.2	123.51	12.0	187.31
28.6	89.47	26.1	124.45	11.0	189.83
28.5	91.70	26.0	125.38	10.0	192.23
28.4	93.79	25.9	126.28	9.0	194.52
28.3	95.78	25.8	127.17	8.0	196.73
28.2	97.67	25.7	128.04	7.0	198.87
28.1	99.45	25.6	128.90	6.0	200.94
28.0	101.15	25.5	129.75	5.0	202.92
27.9	102.79	25.4	130.59	4.0	204.85
27.8	104.35	25.3	131.42	3.0	206.71
27.7	105.85	25.2	132.21	2.0	208.52
27.6	107.30	25.1	133.00	1.0	210.28
27.5	108.70	25.0	133.77	0.0	212

*Based on Marks & Davis Steam Tables, copied from "Steam Tables for Condenser Works," Wheeler Condenser and Engineering Co., Carteret, N. J.

Saturated Steam; Gauge Pressure and Temperature*

Zero Gauge Pressure is absolute pressure of 14.7 lbs. per square inch.

Pressure pounds Gauge	Temperature Deg. F.	Pressure pounds Gauge	Temperature Deg. F.	Pressure pounds Gauge	Temperature Deg. F.
0	212.	36	281.9	71	316.9
1	215.3	37	283.1	72	317.7
2	218.5	38	284.3	73	318.5
3	221.5	39	285.5	74	319.3
4	224.4	40	286.7	75	320.1
5	227.2				
6	229.8	41	287.9	76	320.9
7	232.4	42	289.0	77	321.6
8	234.8	43	290.2	78	322.4
9	237.1	44	291.3	79	323.2
10	239.4	45	292.4	80	323.9
11	241.6	46	293.5	81	324.7
12	243.7	47	294.6	82	325.4
13	245.8	48	295.6	83	326.2
14	247.8	49	296.7	84	326.9
15	249.7	50	297.7	85	327.6
16	251.6	51	298.7	86	328.4
17	253.5	52	299.7	87	329.1
18	255.3	53	300.7	88	329.8
19	257.1	54	301.7	89	330.5
20	258.8	55	302.6	90	331.2
21	260.5	56	303.6	91	331.8
22	262.1	57	304.5	92	332.5
23	263.7	58	305.5	93	333.2
24	265.3	59	306.4	94	333.9
25	266.9	60	307.3	95	334.6
26	268.3	61	308.2	96	335.2
27	269.8	62	309.1	97	335.9
28	271.3	63	310.0	98	336.6
29	272.7	64	310.9	99	337.2
30	274.1	65	311.8	100	337.9
31	275.4	66	312.6	101	338.5
32	276.8	67	313.5	102	339.2
33	278.1	68	314.4	103	339.8
34	279.4	69	315.2	104	340.4
35	280.6	70	316.0	105	341.1

*Based on Marks & Davis Steam Tables, copied from "Steam Tables for Condenser Works," Wheeler Condenser and Engineering Co., Carteret, N. J.

Saturated Steam; Gauge Pressure and Temperature—Continued

Pressure pounds Gauge	Temperature Deg. F.	Pressure pounds Gauge	Temperature Deg. F.	Pressure pounds Gauge	Temperature Deg. F.	Pressure pounds Gauge	Temperature Deg. F.
106	341.7	146	364.0	186	382.2	330	430.
107	342.3	147	364.5	187	382.6	355	432.
108	343.0	148	365.0	188	383.0	340	433.
109	343.6	149	365.5	189	383.4	345	434.
110	344.2	150	365.9	190	383.9	350	436.
111	344.8	151	366.4	191	384.3	355	438.
112	345.4	152	366.9	192	384.7	360	439.
113	346.0	153	367.4	193	385.1	365	440.
114	346.6	154	367.9	194	385.5	370	441.
115	347.2	155	368.4	195	385.9	375	442.
116	347.8	156	368.8	196	386.3	380	443.
117	348.4	157	369.3	197	386.7	385	444.
118	348.9	158	369.8	198	387.1	390	446.
119	349.5	159	370.3	199	387.5	395	447.
120	350.1	160	370.7	200	387.9	400	448.
121	350.7	161	371.3	205	390.	405	449.
122	351.2	162	371.6	210	392.	410	450.
123	351.8	163	372.2	215	393.	415	451.
124	352.4	164	372.6	220	395.	420	453.
125	352.9	165	373.0	225	397.	425	454.
126	353.5	166	373.5	230	399.	430	455.
127	354.0	167	373.9	235	401.	435	457.
128	354.6	168	374.4	240	402.	440	458.
129	355.1	169	374.8	245	406.	445	459.
130	355.7	170	375.3	250	406.	450	460.
131	356.2	171	375.7	255	408.	455	461.
132	356.7	172	376.2	260	409.	460	462.
133	357.3	173	376.6	265	410.	465	463.
134	357.8	174	377.1	270	412.	470	464.
135	358.3	175	377.5	275	414.	475	465.
136	358.9	176	377.9	280	415.	480	466.
137	359.4	177	378.4	285	417.	485	467
138	359.9	178	378.8	290	419.	490	468.
139	360.4	179	379.2	295	420.	495	469.
140	360.9	180	379.7	300	421.	500	470.
141	361.4	181	380.1	305	423.		
142	362.0	182	380.5	310	424.		
143	362.5	183	380.9	315	426.		
144	363.0	184	381.3	320	428.		
145	363.4	185	381.8	325	429.		

Above 200 lbs. gauge taken from Landolt-Bornstein Phys.-Chem. Tables.
See Olsen Chem. Annual 6th. Ed. P. 657
1000 lbs. gauge = 546°F.

Approximate Viscosities of Mixtures *

From the Chart on page 123, the percentage of two given oils of known viscosity that must be used to produce a mixture, or blend, of specified viscosity, can be determined.

Place a straight-edge so that it intersects the scale at right side of chart at the point which is equal to the viscosity of the light oil, and the scale at left side of chart at the point which is equal to the viscosity of the heavy oil.

Project a horizontal line from the point on the scale at either side of chart, equal to the specified viscosity, until it intersects the straight-edge. A vertical line projected from the point of intersection to the top and bottom scales gives the required percentage of heavy and light oils respectively.

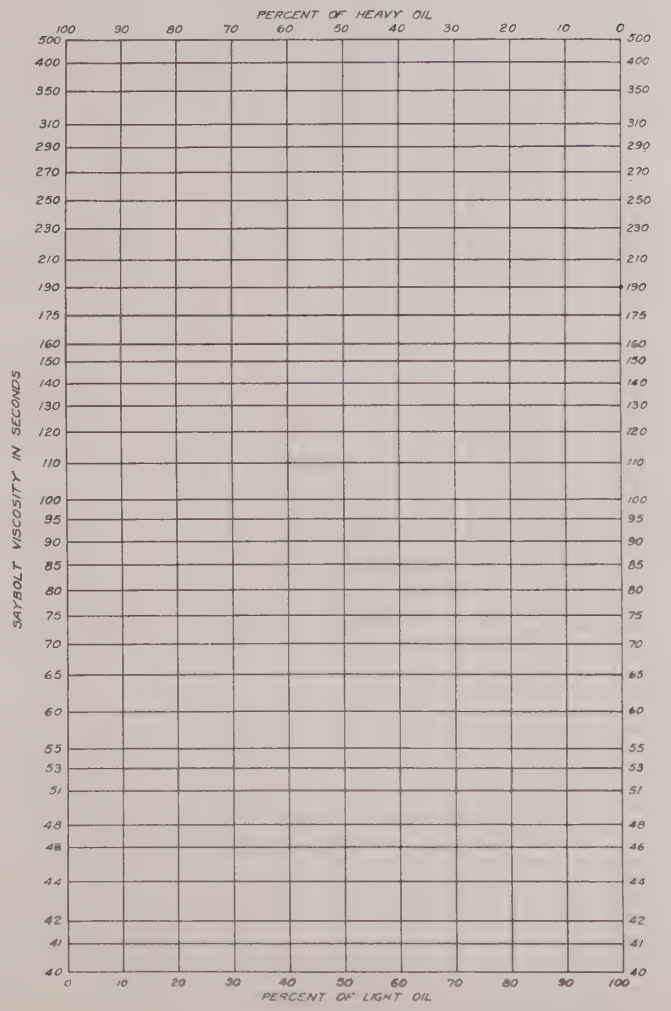
Example: It is desired to produce a mixture having a viscosity of 100 seconds from a heavy oil with a viscosity of 310 seconds and a light oil with a viscosity of 55 seconds.

Place the straight-edge so that it intersects the scale at left at 310 and the scale at right at 55. From the point of intersection of the straight-edge and the horizontal line marked 100, project a vertical line to the top and bottom scales. These show, respectively, that 40% of heavy oil and 60% of light oil should be used.

All three viscosities are at the same temperature and expressed in Saybolt Universal values.

*Data from Bureau of Standards Technologic Paper No. 164.

APPROXIMATE VISCOSITIES OF MIXTURES



Physical and Chemical Constants of Fixed Oils, Fats, Waxes, etc.*

Most of the materials listed have rather wide ranges for nearly all of the tests given. The values in the upper space are the high limit; in the lower space the low limit.

Name of Oil	Specific Gravity 60°/60°F.	Flash Test °F. Open cup	Pour Test °F.	Viscosity Saybolt Universal		Iodine Number
				100°F.	212°F.	
Almond	0.920	...	18	....	...	100
	0.917	...	0	....	...	....
Bone	0.918	445	80	....	65	55.8
	.....	...	....	....	...	46
Castor	0.970	555	19	1500	120	86
	0.960	...	— 1	....	...	....
Cocoanut	0.925	520	70	140	45	8.4
Cod	0.928	460	20	150	50	167
	0.921	...	....	....	...	....
Corn	0.924	550	0	....	54	115
Cotton	0.925	605	25	176	53	110
	0.921	...	10	....	...	108
Lard	0.918	600	60	210	55	63
	0.914	450	30	190	53	....
Linseed raw	0.939	550	10	143	50	201
	0.931	...	—17	....	....	171
Menhaden	0.933	...	25	140	50	173
	0.931	530	20	....	...	139
Neatsfoot	0.917	570	45	230	56	70
	.....	460	20	....	...	....
Olive	0.918	600	35	200	58	88
	0.916	...	....	....	....	79

*Courtesy of L. R. Adkin Vacuum Oil Co.

Physical and Chemical Constants of Fixed Oils, Fats, Waxes, etc.—Continued

Name of Oil	Saponification Number	Free Fatty Acids %	Titer Test °C.	Iodine No. Free Fatty Acids	Special Identifying Tests
Almond	199	....	11.8	96.5	
	...	1.5	10.1	93	
Bone	195	35	....	....	
	191	....	...	...	
Castor	187	7	....	93	150 Acelyl Value
	176	.1	....	87	
Cocoanut	260	25	25.2	9.3	
	...	2.5	22.5	8.4	
Cod	189	15	24	170	
	...	.5	....	130.5	
Corn	195	....	....	....	
Cotton	197	....	35	115	Halphen Test
	191	0	....	111	
Lard	198	30	40	64	
	192				
Linseed raw	195	4.2	21	182	Iodine Number
	192	0.4	19	179	
Menhaden	191	5	....	....	Iodine Number
	...	3	....	....	and Odor
Neatsfoot	204	30	26.5	70	
	193	.3	....	62	
Olive	196	25	26.4	90	
	...	....	17.1	86	

Physical and Chemical Constants of Fixed Oils, Fats, Waxes, etc.—Continued

Name of Oil	Specific Gravity 60°/60° F.	Flash Tert °F. Open cup	Pour Test °F.	Viscosity Saybolt Universal		Iodine Number
				100° F.	212° F.	
Palm	0.924	440	....	221	56	57
	0.921	...	....	....	..	51.5
Peanut	0.920	620	30	195	55	103
	.....	540	....	....	..	97
Rape	0.919	630	20	250	59	109
	0.913	530	— 0	....	55	95
Rosin	1.010	360	....	1500	..	115
	0.960	...	....	....	..	23
Sesame	0.923	510	10	184	54	109
	.....	...	....	....	..	103
Soja Bean	0.929	540	10	165	54	132
	0.924	...	....	....	..	121
Sperm	0.883	...	30	110	42	90
	.....	505	....	....	..	80
Tallow	0.918	600	70	....	56	60
	.....	..	....	..	..	55.5
Tung	0.943	...	— 0	..	..	165
(Chinese wood)	0.936	..	....	..	.	150
Whale	0.925	455	15	163	52	130
	.....	..	..	....	..	100

Physical and Chemical Constants of Fixed Oils, Fats, Waxes, etc.—Continued

Name of Oil	Saponification Number	Free Fatty Acids %	Titer Test °C.	Iodine No. Free Fatty Acids	Special Identifying Tests
Palm	202	90	45.5	53.3	Saponification Value
	196	12	36	.....	
Peanut	197	5.	29	103	
	186	.6	....	96	
Rape	179	....	13	103	Saponification Value
	170	0.3	....	.....	
Rosin	80	35	..		
	70	0	...	...	
Sesame	193	3.5	24	110	Baudouin Test
	184	....	....	.....	
Soja Bean	197	2	24	130	
	189	..	....	119	
Sperm	140	..	11.9	85.6	Sp. Gr. and Saponification
	120	....	....	82.7	
Tallow	198	5	43	57	
	193	....	38	55	
Tung	193	6	....	159	Solidifies at 540° F.
(Chinese Wood)	...	3	....	144	
Whale	197	2	24	131.2	

Physical and Chemical Constants of Fixed Oils, Fats, Waxes, etc.—Continued

Name of Fat or Wax	Specific Gravity 60° 60° F.	Flash Test °F. Open cup	Pour Test °F.	Viscosity Saybolt Universal 110° F.	Viscosity Saybolt Universal 212° F.	Iodine Number
Beeswax	0.970	.	..	. .	. .	11
	.....	...	.	...	..	.6
Carnaiiba	0.999	...	..	...	. .	13.5
Cotton Stearine	0.923	605	70	...	...	103
	.....	...	..	...	..	90
Horse	0.919	590	80	...	55	80
Tallow, beef	0.918	590	..	...	55	45
	.....	...	..	...	...	36
Tallow, mutton	0.918	590	..	...	56	45
	.....	...	..	...	...	36
Wool Grease	0.944	450	..	...	135	29
	.....	...	..	...	...	15
Miscellaneous						
Stearic Acid	0.887	390	..	...	...	..
Red Oil	0.906	370	80	125	...	90
	0.895	...	..	105	. .	..

Physical and Chemical Constants of Fixed Oils, Fats, Waxes, etc.—Continued

Name of Fat or Wax	Saponification Number	Free Fatty Acids %	Titer Test °C.	Iodine No. Free Fatty Acids	Melting Point °F.	Melting Point °C.
Beeswax	98	10.6	....	....	147	63.9
	.	8.4	.	. .	...	....
Carnaiiba	95	3.5	....	....	183	83.9
	...	2	....	....	..	....
Cotton Stearine	195	....	45	34.4	104	40
	...	....	35	....	86	30
Horse	195	10	45	87	109	443
	...	0	....	72	95	35
Tallow, beef	195	10	47	41.3	120	48.9
	...	3.5	37.9	....	105	40.6
Tallow, mutton	195	10	48.	41.3	130	54.4
	...	1.7	40.1	..	..	....
Wool grease	102	60	....	....	125	51.7
	...	....	....	.	95	35
Miscellaneous						
Stearic Acid	...	100	....	....	135	57.2
Red Oil	200	97	37	.	...	....
	...	50	13	. .	...	....

Potassium Hydroxide Solutions

(Caustic Potash)
By Lunge

Specific Gravity 60°/60° F.	Degrees Baumé	Degrees Twaddle*	Per Cent. KOH	Grams KOH Per Liter
1.007	1.0	1.4	0.9	9
1.014	2.0	2.8	1.7	17
1.022	3.1	4.4	2.6	26
1.029	4.1	5.8	3.5	36
1.037	5.2	7.4	4.5	46
1.045	6.2	9.0	5.6	58
1.052	7.2	10.4	6.4	67
1.060	8.2	12.0	7.4	78
1.067	9.1	13.4	8.2	83
1.075	10.1	15.0	9.2	99
1.083	11.1	16.6	10.1	109
1.091	12.1	18.2	10.9	119
1.100	13.2	20.0	12.0	132
1.108	14.1	21.6	12.9	143
1.116	15.1	23.2	13.8	153
1.125	16.1	25.0	14.8	167
1.134	17.1	26.8	15.7	178
1.142	18.0	28.4	16.5	183
1.152	19.1	30.4	17.6	203
1.162	20.2	32.4	18.6	216
1.171	21.2	34.2	19.5	228
1.180	22.1	36.0	20.5	242
1.190	23.1	38.0	21.4	255
1.200	24.2	40.0	22.4	269
1.210	25.2	42.0	23.3	282
1.220	26.1	44.0	24.2	295
1.231	27.2	46.2	25.1	309
1.241	28.2	48.2	26.1	324
1.252	29.2	50.4	27.0	338

Potassium Hydroxide Solutions—Continued

Specific Gravity 66°/60° F.	Degrees Baumé	Degrees Twaddle	Per Cent. KOH	Grams KOH Per Liter
1.263	30.2	52.6	28.0	353
1.274	31.2	54.8	28.9	368
1.285	32.2	57.0	29.8	385
1.297	53.2	59.4	30.7	398
1.308	34.1	61.6	31.8	416
1.320	35.2	64.0	32.7	432
1.332	36.1	66.4	33.7	449
1.345	37.2	69.0	34.9	469
1.357	38.1	71.4	35.9	487
1.370	39.2	74.0	36.9	506
1.383	40.2	76.6	37.8	522
1.397	41.2	79.4	38.9	543
1.410	42.2	82.0	39.9	563
1.424	43.2	84.8	40.9	582
1.438	44.2	87.6	42.1	605
1.453	45.2	90.6	43.4	631
1.468	46.2	93.6	44.6	655
1.483	47.2	96.6	45.8	679
1.498	48.2	99.6	47.1	706
1.514	49.2	102.8	48.3	731
1.530	50.2	106.0	49.4	756
1.546	51.2	109.2	50.6	779
1.563	52.2	112.6	51.9	811
1.580	53.2	116.0	53.2	840
1.597	54.2	119.4	54.5	870
1.615	55.2	123.0	55.9	905
1.634	56.3	126.8	57.5	940

Sodium Hydroxide Solutions

(Caustic Soda)
By LUNGE

Specific Gravity 60°/60° F.	Degrees Baumé	Degrees Twaddle*	Per Cent. NaOH	Grams NaOH Per Liter
1.007	1.0	1.4	0.61	6
1.014	2.0	2.8	1.20	12
1.022	3.1	4.4	2.00	21
1.029	4.1	5.8	2.70	28
1.036	5.1	7.2	3.35	35
1.045	6.2	9.0	4.00	42
1.052	7.2	10.4	4.64	49
1.060	8.2	12.0	5.29	56
1.067	9.1	13.4	5.87	63
1.075	10.1	15.0	6.55	70
1.083	11.1	16.6	7.31	79
1.091	12.1	18.2	8.00	87
1.100	13.2	20.0	8.68	95
1.108	14.1	21.6	9.42	104
1.116	15.1	23.2	10.06	112
1.125	16.1	25.0	10.97	123
1.134	17.1	26.8	11.84	134
1.142	18.0	28.4	12.64	144
1.152	19.1	30.4	13.55	156
1.162	20.2	32.4	14.37	167
1.171	21.2	34.2	15.13	177
1.180	22.1	36.0	15.91	188
1.190	23.1	38.0	16.77	200
1.200	24.2	40.0	17.67	212
1.210	25.2	42.0	18.58	225
1.220	26.1	44.0	19.58	239
1.231	27.2	46.2	20.59	253
1.241	28.2	48.2	21.42	266
1.252	29.2	50.4	22.64	283

Sodium Hydroxide Solutions—Continued

Specific Gravity 60°/60° F.	Degrees Baumé	Degrees *Twaddle	Per Cent. NaOH	Grams NaOH Per Liter
1.263	30.2	52.6	23.67	299
1.274	31.2	54.8	24.81	316
1.285	32.2	57.0	25.80	332
1.297	33.2	59.4	26.83	348
1.308	34.1	61.6	27.80	364
1.320	35.2	64.0	28.83	381
1.332	36.1	66.4	29.93	399
1.345	37.2	69.0	31.22	420
1.357	38.1	71.4	32.47	441
1.370	39.2	74.0	33.69	462
1.383	40.2	76.6	34.96	483
1.397	41.2	79.4	36.25	506
1.410	42.2	82.0	37.47	528
1.424	43.2	84.8	38.80	553
1.438	44.2	87.6	39.99	575
1.453	45.2	90.6	41.41	602
1.468	46.2	93.6	42.83	629
1.483	47.2	96.6	44.38	658
1.498	48.2	99.6	46.15	691
1.514	49.2	102.8	47.60	721
1.530	50.2	106.0	49.02	750

*Twaddle values are derived from specific gravity by the following formula:

$$\text{Twaddle} = (200 \times \text{Sp. Gr.}) - 200$$

$$\text{Specific Gravity} = \frac{\text{Tw.} + 200}{200}$$

Sulphuric Acid*

By W. C. Ferguson and H. P. Talbot

Degrees Baumé	Specific Gravity 60°/60° F.	Per Cent. H_2SO_4	Degrees Baumé	Specific Gravity 60°/60° F.	Per Cent. H_2SO_4
0	1.0000	0.00	30	1.2609	34.63
1	1.0069	1.02	31	1.2719	35.93
2	1.0140	2.08	32	1.2832	37.26
3	1.0211	3.13	33	1.2946	38.58
4	1.0284	4.21	34	1.3063	39.92
5	1.0357	5.28	35	1.3182	41.27
6	1.0432	6.37	36	1.3303	42.63
7	1.0507	7.45	37	1.3426	43.99
8	1.0584	8.55	38	1.3551	45.35
9	1.0662	9.66	39	1.3679	46.72
10	1.0741	10.77	40	1.3810	48.10
11	1.0821	11.89	41	1.3942	49.47
12	1.0902	13.01	42	1.4078	50.87
13	1.0985	14.13	43	1.4216	52.26
14	1.1069	15.25	44	1.4356	53.66
15	1.1154	16.38	45	1.4500	55.07
16	1.1240	17.53	46	1.4646	56.48
17	1.1328	18.71	47	1.4796	57.90
18	1.1417	19.89	48	1.4948	59.32
19	1.1508	21.07	49	1.5104	60.75
20	1.1600	22.25	50	1.5263	62.18
21	1.1694	23.43	51	1.5462	63.36
22	1.1789	24.61	52	1.5591	65.61
23	1.1885	25.81	53	1.5761	66.63
24	1.1983	27.03	54	1.5934	68.13
25	1.2083	28.28	55	1.6111	69.65
26	1.2185	29.53	56	1.6292	71.17
27	1.2288	30.79	57	1.6477	72.75
28	1.2393	32.05	58	1.6667	74.36
29	1.2500	33.33	59	1.6860	75.99

Sulphuric Acid—Continued

Degrees Baumé	Specific Gravity 60°/60° F.	Per Cent. H_2SO_4	Degrees Baumé	Specific Gravity 60°/60° F.	Per Cent. H_2SO_4
60	1.7059	77.67	64¼	1.7957	66.33
61	1.7262	79.43	64½	1.8012	87.04
62	1.7470	81.30	64¾	1.8068	87.81
63	1.7683	83.34	65	1.8125	88.65
64	1.7901	85.66	65¼	1.8182	89.55
			65½	1.8239	90.60
			65¾	1.8297	91.80
			66	1.8354	93.19

Sp. Gr. determinations were made at 60° F., compared with water at 60° F.

From the Sp. Grs., the corresponding degrees Baumé were calculated by the following formula: Baumé = 145—145/Sp. Gr.

Allowance for Temperatures

At 10° Bé.	correction of	.029°	Bé. or	.00023	Sp. Gr.	for every	1° F.
" 20°	"	"	"	.036°	"	"	.00034	"	"	"	"	1° F.
" 30°	"	"	"	.035°	"	"	.00039	"	"	"	"	1° F.
" 40°	"	"	"	.031°	"	"	.00041	"	"	"	"	1° F.
" 50°	"	"	"	.028°	"	"	.00045	"	"	"	"	1° F.
" 60°	"	"	"	.026°	"	"	.00053	"	"	"	"	1° F.
" 63°	"	"	"	.026°	"	"	.00057	"	"	"	"	1° F.
" 66°	"	"	"	.0235°	"	"	.00054	"	"	"	"	1° F.

For temperatures above 60° F., the correction is added to the observed indication; below 60° F., subtracted.

*This table was approved and adopted as a standard by the Manufacturing Chemists' Association of the United States, June 23, 1904.

Sodium Chloride Na Cl

Jessup; Bureau of Standards. Refrigerating Engineering Dec. 1925.

Sp. Gr. 60°/60°F.	°Baume 60°F.	°Salinometer 60°F.	% Na Cl by weight	Freezing Point °F.
1.000	0.0	0	0	+32.0
1.007	1.0	....	1	31.1
1.014	2.0	....	2	30.1
1.019	2.7	10.	2.7	29.3
1.021	3.0	....	3	29.0
1.028	4.0	....	4	27.9
1.036	5.0	....	5	26.7
1.038	5.3	20	5.3	26.4
1.043	6.0	....	6	25.5
1.051	7.0	....	7	24.2
1.058	8.0	30	8	22.9
1.066	9.0	....	9	21.6
1.073	9.9	....	10	20.2
1.078	10.5	40	10.6	19.4
1.081	10.9	....	11	18.8
1.088	11.7	....	12	17.3
1.096	12.7	....	13	15.7
1.098	12.9	50	13.2	15.4
1.104	13.7	....	14	14.1
1.112	14.6	....	15	12.4
1.118	15.3	60	15.8	10.8
1.119	15.4	....	16	10.6
1.127	16.3	....	17	8.7
1.135	17.3	....	18	6.7
1.139	17.7	70	18.5	5.7
1.143	18.1	....	19	4.6
1.151	19.0	....	20	+ 2.4
1.159	19.9	....	21	0.0
1.161	20.1	80	21.2	−0.6
1.167	20.8	....	22	2.5
1.176	21.7	....	23	5.2
1.182	22.3	90	23.8	−0.8
1.184	22.5	....	24	+ 1.4
1.192	23.4	....	25	13.3
1.201	24.3	....	26	....

Sodium Chloride Na Cl—Continued

Jessup; Bureau of Standards. Refrigerating Engineering Dec. 1925.

Sp. Gr. 60°/60°F.	°Baume 60°F.	°Salinometer 60°F.	% Na Cl by weight	Freezing Point °F.
1.204	24.6	100	26.4	....
1.226	26.7	110	....	....
1.249	28.9	120	....	....
1.271	30.9	130	....	....

Temperature Correction in °Salometer for every °F. Add for temperatures above 60°F.; subtract below.

Reading	Correction	Reading	Correction
0°	.02	70°	.08
10°	.03	80°	.09
20°	.05	90°	.10
40°	.06	100°	.11
50°	.07		

Calcium Chloride $CaCl_2$ (Pure)

Jessup; Bureau of Standards. Refrigerating Engineering Dec. 1925.

Commercial Calcium Chloride averages about 73% pure, to obtain percent of commercial salt divide the percent pure given in the table by .73.

Sp. Gr. 60°/60°F.	°Baume 60°F	°Salinometer 60°F	%Na Cl^2 by weight	Freezing Point °F.
1.000	0.0	0	0	+32.0
1.008	1.15	4.6	1	31.6
1.017	2.42	9.7	2	30.2
1.018	2.50	10.0	2.1	30.1
1.026	3.68	14.7	3	29.3
1.034	4.77	19.1	4	28.4
1.036	5.00	20.0	4.2	28.2
1.043	5.98	23.9	5	27.5
1.052	7.17	28.7	6	26.4
1.055	7.50	30.0	6.3	26.1
1.060	8.21	32.8	7	25.3
1.069	9.36	37.4	8	24.2
1.074	10.00	40.0	8.6	23.4
1.078	10.49	42.0	9	22.8
1.087	11.61	46.4	10	21.4
1.094	12.50	50.0	10.8	20.1
1.096	12.70	50.8	11	19.8
1.105	13.78	55.1	12	18.2
1.114	14.84	59.4	13	16.3
1.115	15.00	60.0	13.1	16.1
1.124	16.00	64.0	14	14.4
1.133	17.03	68.1	15	12.2
1.137	17.50	70.0	15.4	11.3
1.143	18.14	72.5	16	9.9
1.152	19.13	76.5	17	7.4
1.160	20.0	80.0	17.8	5.4
1.162	20.24	81.0	18	4.7
1.172	21.28	85.1	19	+ 1.9
1.182	22.33	89.3	20	− 1.0
1.184	22.50	90.0	20.2	1.6

Calcium Chloride $CaCl_2$ (Pure)—Continued

Sp. Gr. 60°/60°F.	°Baume 60°F	°Salinometer 60°F	%Na Cl_2 by weight	Freezing Point °F.
1.192	23.36	93.4	21	4.0
1.202	24.37	97.5	22	7.3
1.208	25.00	100.0	22.6	9.3
1.212	25.36	101.4	23	10.6
1.223	26.44	105.8	24	14.1
1.233	27.40	109.6	25	18.0
1.234	27.50	110.0	25.1	18.4
1.244	28.44	113.8	26	22.0
1.254	29.37	117.5	27	27.0
1.261	30.0	120.0	27.6	30
1.265	30.38	121.5	28	32.0
1.276	31.36	125.4	29	39.0
1.287	32.34	129.4	30	46.0
1.289	32.50	130.0	30.16	47.0
1.290	32.60	130.4	30.26	−48.0

Aqua Ammonia*

By W. C. Ferguson

Degrees Baumé	Specific Gravity 60°/60° F.	Per Cent. NH_3	Degrees Baumé	Specific Gravity 60°/60° F.	Per Cent. NH_3
10.00	1.0000	.00	18.75	.9412	15.37
10.25	.9982	.40	19.00	.9396	15.84
10.50	.9964	.80	19.25	.9380	16.32
10.75	.9947	1.21	19.50	.9365	16.80
11.00	.9929	1.62	19.75	.9349	17.28
11.25	.9912	2.04	20.00	.9333	17.76
11.50	.9894	2.46	20.25	.9318	18.24
11.75	.9876	2.88	20.50	.9302	18.72
12.00	.9859	3.30	20.75	.9287	19.20
12.25	.9842	3.73	21.00	.9272	19.68
12.50	.9825	4.16	21.25	.9256	20.16
12.75	.9807	4.59	21.50	.9241	20.64
13.00	.9790	5.02	21.75	.9226	21.12
13.25	.9773	5.45	22.00	.9211	21.60
13.50	.9756	5.88	22.25	.9195	22.08
13.75	.9739	6.31	22.50	.9180	22.56
14.00	.9722	6.74	22.75	.9165	23.04
14.25	.9705	7.17	23.00	.9150	23.52
14.50	.9689	7.61	23.25	.9135	24.01
14.75	.9672	8.05	23.50	.9121	24.50
15.00	.9655	8.49	23.75	.9106	24.99
15.25	.9639	8.93	24.00	.9091	25.48
15.50	.9622	9.38	24.25	.9076	25.97
15.75	.9605	9.83	24.50	.9061	26.46
16.00	.9589	10.28	24.75	.9047	26.95
16.25	.9573	10.73	25.00	.9032	27.44
16.50	.9556	11.18	25.25	.9018	27.93
16.75	.9540	11.64	25.50	.9003	28.42
17.00	.9524	12.10	25.75	.8989	28.91
17.25	.9508	12.56	26.00	.8974	29.40
17.50	.9492	13.02	26.25	.8960	29.89
17.75	.9475	13.49	26.50	.8946	30.38
18.00	.9459	13.96	26.75	.8931	30.87
18.25	.9444	14.43	27.00	.8917	31.36
18.50	.9428	14.90	27.25	.8903	31.85

Aqua Ammonia—Continued

Degrees Baumé	Specific Gravity 60°/60° F.	Per Cent. NH_3	Degrees Baumé	Specific Gravity 60°/60° F.	Per Cent. NH_3
27.50	.8889	32.34	28.50	.8833	34.30
27.75	.8875	32.83	28.75	.8819	34.79
28.00	.8861	33.32	29.00	.8805	35.28
28.25	.8847	33.81			

Specific Gravity determinations were made at 60° F., compared with water at 60° F.

From the Specific Gravities the corresponding degrees Baumé were calculated by the following formula:

$$\text{Baumé} = \frac{140}{\text{Sp. Gr.}} - 130.$$

Allowance for Temperature

The coefficient of expansion for ammonia solutions, varying with the temperature, correction must be applied according to the following table:

Degrees Baumé	Corrections to be Added for Each Degree Below 60° F.		Corrections to be Subtracted for Each Degree Above 60° F.			
	40° F.	50° F.	70° F.	80° F.	90° F.	100°F.
14° Bé.	.015° Bé.	.017° Bé.	.020° Bé.	.022° Bé.	.024° Bé.	.026°Bé.
16° "	.021° "	.023° "	.026° "	.028° "	.030° "	.032° "
18° "	.027° "	.029° "	.031° "	.033° "	.035° "	.037° "
20° "	.033° "	.036° "	.037° "	.038° "	.040° "	.042° "
22° "	.039° "	.042° "	.043° "	.045° "	.047° "	
26° "	.053° "	.057° "	.057° "	.059° "		

*This table was approved and adopted as a Standard by the Manufacturing Chemists' Association of the United States, May 14, 1903.

Saturated Ammonia Vapor; Pressure and Corresponding Temperature

These values are from circular No. 142 of the Bureau of Standards, "Tables of Thermodynamic Properties of Ammonia" 1923.

Pressure Lbs. Gauge	Temp. °F.	Pressure Lbs. Gauge	Temp. °F.	Pressure Lbs. Gauge	Temp. °F.
20*	−63.9	15	−1.0	50	33.8
19*	−61.0	16	+0.4	51	34.6
18*	−58.4	17	1.7	52	35.3
17*	−55.9	18	3.0	53	36.1
16*	−53.6	19	4.3	54	36.8
15*	−51.4	20	5.5	55	37.5
14*	−49.4	21	6.7	56	38.2
13*	−47.4	22	7.9	57	38.9
12*	−45.6	23	9.1	58	39.6
11*	−43.8	24	10.2	59	40.3
10*	−42.1	25	11.3	60	40.9
9*	−40.4	26	12.4	61	41.6
8*	−38.9	27	13.5	62	42.3
7*	−37.3	28	14.5	63	42.9
6*	−35.9	29	15.6	64	43.6
5*	−34.5	30	16.6	65	44.2
4*	−33.1	31	17.6	66	44.8
3*	−31.8	32	18.6	67	45.5
2*	−30.5	33	19.5	68	46.1
1*	−29.2	34	20.5	69	47.7
0	−28.0	35	21.4	70	47.3
1	−25.6	36	22.3	71	47.9
2	−23.4	37	23.2	72	48.5
3	−21.2	38	24.1	73	49.1
4	−19.2	39	25.0	74	49.7
5	−17.2	40	25.8	75	50.3
6	−15.3	41	26.7	76	50.9
7	−13.5	42	27.5	77	51.5
8	−11.8	43	28.3	78	52.0
9	−10.1	44	29.2	79	52.6
10	− 8.4	45	30.0	80	53.1
11	− 6.9	46	30.8	81	53.7
12	− 5.3	47	31.5	82	54.3
13	− 3.8	48	32.3	83	54.8
14	− 2.4	49	33.1	84	55.3

*Inches of mercury below one atmosphere (29.92 in).

Saturated Ammonia Vapor; Pressure and Corresponding Temperature—Continued

Pressure Lbs. Gauge	Temp. °F.	Pressure Lbs. Gauge	Temp. °F.	Pressure Lbs. Gauge	Temp. °F.
85	55.9	140	80.6	225	108.0
86	56.4	142	81.4	230	109.4
87	57.0	144	82.2	235	110.7
88	57.5	146	82.9	240	112.0
89	58.0	148	83.6	245	113.3
90	58.5	150	84.4	250	114.6
91	59.0	152	85.1	255	115.9
92	59.6	154	85.8	260	117.1
93	60.1	156	86.5	265	118.4
94	60.6	158	87.2	270	119.6
95	61.1	160	88.0	275	120.8
96	61.6	162	88.6	280	122.0
97	62.0	164	89.3	285	123.1
98	62.5	166	90.0	290	124.3
99	63.0	168	90.7	295	125.4
100	63.5	170	91.4	300	126.5
102	64.5	172	92.0	....	....
104	65.4	174	92.7	....	....
106	66.4	176	93.4	....	....
108	67.3	178	94.0	....	....
110	68.2	180	94.7	....	....
112	69.1	182	95.3	....	....
114	70.0	184	95.9	....	....
116	70.8	186	96.6	....	....
118	71.7	188	97.2	....	....
120	72.6	190	97.8	....	....
122	73.4	192	98.4	....	....
124	74.2	194	99.0	....	....
126	75.1	196	99.7	....	....
128	75.9	198	100.3	....	....
130	76.7	200	100.9	....	....
132	77.5	205	102.3	....	....
134	78.3	210	103.8	....	....
136	79.1	215	105.2	....	....
138	79.9	220	106.6	....	....

Correction of Flash Point for Barometric Pressures

The true flash point of an oil flashing between 20° and 50°C. (on oils flashing above 50° C. readings are not required so close and this correction can therefore be neglected) is obtained by correcting the indicated flash point for barometric pressure by using the following table. 760 mm. is considered the standard normal barometric pressure, and all indication should be corrected thereto.

Barometer Reading, mm.

760	650	655	660	665	670	675	680	685	690
			Flash Point, °C.						
19.0	15.5	15.6	15.7	15.8	15.9	16.1	16.2	16.4	16.6
19.5	16.0	16.1	16.2	16.3	16.4	16.6	16.7	16.9	17.1
20.0	16.5	16.6	16.7	16.8	16.9	17.1	17.2	17.4	17.6
20.5	17.0	17.1	17.2	17.3	17.4	17.6	17.7	17.9	18.1
21.0	17.5	17.6	17.7	17.8	17.9	18.1	18.2	18.4	18.6
21.5	18.0	18.1	18.2	18.3	18.4	18.6	18.7	18.9	19.1
22.0	18.5	18.6	18.7	18.8	18.9	19.1	19.2	19.4	19.6
22.5	19.0	19.1	19.2	19.3	19.4	19.6	19.7	19.9	20.1
23.0	19.5	19.6	19.7	19.8	19.9	20.1	20.2	20.4	20.6
23.5	20.0	20.1	20.2	20.3	20.4	20.6	20.7	20.9	21.1
24.0	20.5	20.6	20.7	20.8	20.9	21.1	21.2	21.4	21.6
24.5	21.0	21.1	21.2	21.3	21.4	21.6	21.7	21.9	22.1
25.0	21.5	21.6	21.7	21.8	21.9	22.1	22.2	22.4	22.6
25.5	22.0	22.1	22.2	22.3	22.4	22.6	22.7	22.9	23.1
26.0	22.5	22.6	22.7	22.8	22.9	23.1	23.2	23.4	23.6
26.5	23.0	23.1	23.2	23.3	23.4	23.6	23.7	23.9	24.1
27.0	23.5	23.6	23.7	23.8	23.9	24.1	24.2	24.4	24.6
27.5	24.0	24.1	24.2	24.3	24.4	24.6	24.7	24.9	25.1
28.0	24.5	24.6	24.7	24.8	24.9	25.1	25.2	25.4	25.6
28.5	25.0	25.1	25.2	25.3	25.4	25.6	25.7	25.9	26.1
29.0	25.5	25.6	25.7	25.8	25.9	26.1	26.2	26.4	26.6
29.5	26.0	26.1	26.2	26.3	26.4	26.6	26.7	26.9	27.1
30.0	26.5	26.6	26.7	26.8	26.9	27.1	27.2	27.4	27.6
30.5	27.0	27.1	27.2	27.3	27.4	27.6	27.7	27.9	28.1
31.0	27.5	27.6	27.7	27.8	27.9	28.1	28.2	28.4	28.6
31.5	28.0	28.1	28.2	28.3	28.4	28.6	28.7	28.9	29.1
32.0	28.5	28.6	28.7	28.8	28.9	29.1	29.2	29.4	29.6
32.5	29.0	29.1	29.2	29.3	29.4	29.6	29.7	29.9	30.1
33.0	29.5	29.6	29.7	29.8	29.9	30.1	30.2	30.4	30.6
33.5	30.0	30.1	30.2	30.3	30.4	30.6	30.7	30.9	31.1
34.0	30.5	30.6	30.7	30.8	30.9	31.1	31.2	31.4	31.6
34.5	31.0	31.1	31.2	31.3	31.4	31.6	31.7	31.9	32.1
35.0	31.5	31.6	31.7	31.8	31.9	32.1	32.2	32.4	32.6
35.5	32.0	32.1	32.2	32.3	32.4	32.6	32.7	32.9	33.1
36.0	32.5	32.6	32.7	32.8	32.9	33.1	33.2	33.4	33.6
36.5	33.0	33.1	33.2	33.3	33.4	33.6	33.7	33.9	34.1
37.0	33.5	33.6	33.7	33.8	33.9	34.1	34.2	34.4	34.6

Barometer Reading, mm—Continued

760	650	655	660	665	670	675	680	685	690
				Flash Point, °C.					
37.5	34.0	34.1	34.2	34.3	34.4	34.6	34.7	34.9	35.1
38.0	34.5	34.6	34.7	34.8	34.9	35.1	35.2	35.4	35.6
38.5	35.0	35.1	35.2	35.3	35.4	35.6	35.7	35.9	36.1
39.0	35.5	35.6	35.7	35.8	35.9	36.1	36.2	36.4	36.6
39.5	36.0	36.1	36.2	36.3	36.4	36.6	36.7	36.9	37.1
40.0	36.5	36.6	36.7	36.8	36.9	37.1	37.2	37.4	37.6
40.5	37.0	37.1	37.2	37.3	37.4	37.6	37.7	37.9	38.1
41.0	37.5	37.6	37.7	37.8	37.9	38.1	38.2	38.4	38.6
41.5	38.0	38.1	38.2	38.3	38.4	38.6	38.7	38.9	39.1
42.0	38.5	38.6	38.7	38.8	38.9	39.1	39.2	39.4	39.6
42.5	39.0	39.1	39.2	39.3	39.4	39.6	39.7	39.9	40.1
43.0	39.5	39.6	39.7	39.8	39.9	40.1	40.2	40.4	40.6
43.5	40.0	40.1	40.2	40.3	40.4	40.6	40.7	40.9	41.1
44.0	40.5	40.6	40.7	40.8	40.9	41.1	41.2	41.4	41.6
44.5	41.0	41.1	41.2	41.3	41.4	41.6	41.7	41.9	42.1
45.0	41.5	41.6	41.7	41.8	41.9	42.1	42.2	42.4	42.6
45.5	42.0	42.1	42.2	42.3	42.4	42.6	42.7	42.9	43.1
46.0	42.5	42.6	42.7	42.8	42.9	43.1	43.2	43.4	43.6
46.5	43.0	43.1	43.2	43.3	43.4	43.6	43.7	43.9	44.1
47.0	43.5	43.6	43.7	43.8	43.9	44.1	44.2	44.4	44.6
47.5	44.0	44.1	44.2	44.3	44.4	44.6	44.7	44.9	45.1
48.0	44.5	44.6	44.7	44.8	44.9	45.1	45.2	45.4	45.6
48.5	45.0	45.1	45.2	45.3	45.4	45.6	45.7	45.9	46.1
49.0	45.5	45.6	45.7	45.8	45.9	46.1	46.2	46.4	46.6
49.5	46.0	46.1	46.2	46.3	46.4	46.6	46.7	46.9	47.1
50.0	46.5	46.6	46.7	46.8	46.9	47.1	47.2	47.4	47.6
50.5	47.0	47.1	47.2	47.3	47.4	47.6	47.7	47.9	48.1
51.0	47.5	47.6	47.7	47.8	47.9	48.1	48.2	48.4	48.6
51.5	48.0	48.1	48.2	48.3	48.4	48.6	48.7	48.9	49.1
52.0	48.5	48.6	48.7	48.8	48.9	49.1	49.2	49.4	49.6
52.5	49.0	49.1	49.2	49.3	49.4	49.6	49.7	49.9	50.1
53.0	49.5	49.6	49.7	49.8	49.9	50.1	50.2	50.4	50.6
53.5	50.0	50.1	50.2	50.3	50.4	50.6	50.7	50.9	51.1
54.0	50.5	50.6	50.7	50.8	50.9	51.1	51.2	51.4	51.6
54.5	51.0	51.1	51.2	51.3	51.4	51.6	51.7	51.9	52.1
55.0	51.5	51.6	51.7	51.8	51.9	52.1	52.2	52.4	52.6

Barometer Reading, mm—Continued

760	695	700	705	710	715	720	725	730	735
				Flash Point, °C.					
19.0	16.7	16.9	17.1	17.3	17.4	17.6	17.8	18.0	18.1
19.5	17.2	17.4	17.6	17.8	17.9	18.1	18.3	18.5	18.6
20.0	17.7	17.9	18.1	18.3	18.4	18.6	18.8	19.0	19.1
20.5	18.2	18.4	18.6	18.8	18.9	19.1	19.3	19.5	19.6
21.0	18.7	18.9	19.1	19.3	19.4	19.6	19.8	20.0	20.1
21.5	19.2	19.4	19.6	19.8	19.9	20.1	20.3	20.5	20.6
22.0	19.7	19.9	20.1	20.3	20.4	20.6	20.8	21.0	21.1
22.5	20.2	20.4	20.6	20.8	20.9	21.1	21.3	21.5	21.6
23.0	20.7	20.9	21.1	21.3	21.4	21.6	21.8	22.0	22.1
23.5	21.2	21.4	21.6	21.8	21.9	22.1	22.3	22.5	22.6
24.0	21.7	21.9	22.1	22.3	22.4	22.6	22.8	23.0	23.1
24.5	22.2	22.4	22.6	22.8	22.9	23.1	23.3	23.5	23.6
25.0	22.7	22.9	23.1	23.3	23.4	23.6	23.8	24.0	24.1
25.5	23.2	23.4	23.6	23.8	23.9	24.1	24.3	24.5	24.6
26.0	23.7	23.9	24.1	24.3	24.4	24.6	24.8	25.0	25.1
26.5	24.2	24.4	24.6	24.8	24.9	25.1	25.3	25.5	25.6
27.0	24.7	24.9	25.1	25.3	25.4	25.6	25.8	26.0	26.1
27.5	25.2	25.4	25.6	25.8	25.9	26.1	26.3	26.5	26.6
28.0	25.7	25.9	26.1	26.3	26.4	26.6	26.8	27.0	27.1
28.5	26.2	26.4	26.6	26.8	26.9	27.1	27.3	27.5	27.6
29.0	26.7	26.9	27.1	27.3	27.4	27.6	27.8	28.0	28.1
29.5	27.2	27.4	27.6	27.8	27.9	28.1	28.3	28.5	28.6
30.0	27.7	27.9	28.1	28.3	28.4	28.6	28.8	29.0	29.1
30.5	28.2	28.4	28.6	28.8	28.9	29.1	29.3	29.5	29.6
31.0	28.7	28.9	29.1	29.3	29.4	29.6	29.8	30.0	30.1
31.5	29.2	29.4	29.6	29.8	29.9	30.1	30.3	30.5	30.6
32.0	29.7	29.9	30.1	30.3	30.4	30.6	30.8	31.0	31.1
32.5	30.2	30.4	30.6	30.8	30.9	31.1	31.3	31.5	31.6
33.0	30.7	30.9	31.1	31.3	31.4	31.6	31.8	32.0	32.1
33.5	31.2	31.4	31.6	31.8	31.9	32.1	32.3	32.5	32.6
34.0	31.7	31.9	32.1	32.3	32.4	32.6	32.8	33.0	33.1
34.5	32.2	32.4	32.6	32.8	32.9	33.1	33.3	33.5	33.6
35.0	32.7	32.9	33.1	33.3	33.4	33.6	33.8	34.0	34.1
35.5	33.2	33.4	33.6	33.8	33.9	34.1	34.3	34.5	34.6
36.0	33.7	33.9	34.1	34.3	34.4	34.6	34.8	35.0	35.1
36.5	34.2	34.4	34.6	34.8	34.9	35.1	35.3	35.5	35.6
37.0	34.7	34.9	35.1	35.3	35.4	35.6	35.8	36.0	36.1

Barometer Reading, mm—Continued

760	695	700	705	710	715	720	725	730	735
				Flash point, °C.					
37.5	35.2	35.4	35.6	35.8	35.9	36.1	36.3	36.5	36.6
38.0	35.7	35.9	36.1	36.3	36.4	36.6	36.8	37.0	37.1
38.5	36.2	36.4	36.6	36.8	36.9	37.1	37.3	37.5	37.6
39.0	36.7	36.9	37.1	37.3	37.4	37.6	37.8	38.0	38.1
39.5	37.2	37.4	37.6	37.8	37.9	38.1	38.3	38.5	38.6
40.0	37.7	37.9	38.1	38.3	38.4	38.6	38.8	39.0	39.1
40.5	38.2	38.4	38.6	38.8	38.9	39.1	39.3	39.5	39.6
41.0	38.7	38.9	39.1	39.3	39.4	39.6	39.8	40.0	40.1
41.5	39.2	39.4	39.6	39.8	39.9	40.1	40.3	40.5	40.6
42.0	39.7	39.9	40.1	40.3	40.4	40.6	40.8	41.0	41.1
42.5	40.2	40.4	40.6	40.8	40.9	41.1	41.3	41.5	41.6
43.0	40.7	40.9	41.1	41.3	41.4	41.6	41.8	42.0	42.1
43.5	41.2	41.4	41.6	41.8	41.9	42.1	42.3	42.5	42.6
44.0	41.7	41.9	42.1	42.3	42.4	42.6	42.8	43.0	43.1
44.5	42.2	42.4	42.6	42.8	42.9	43.1	43.3	43.5	43.6
45.0	42.7	42.9	43.1	43.3	43.4	43.6	43.8	44.0	44.1
45.5	43.2	43.4	43.6	43.8	43.9	44.1	44.3	44.5	44.6
46.0	43.7	43.9	44.1	44.3	44.4	44.6	44.8	45.0	45.1
46.5	44.2	44.4	44.6	44.8	44.9	45.1	45.3	45.5	45.6
47.0	44.7	44.9	45.1	45.3	45.4	45.6	45.8	46.0	46.1
47.5	45.2	45.4	45.6	45.8	45.9	46.1	46.3	46.5	46.6
48.0	45.7	45.9	46.1	46.3	46.4	46.6	46.8	47.0	47.1
48.5	46.2	46.4	46.6	46.8	46.9	47.1	47.3	47.5	47.6
49.0	46.7	46.9	47.1	47.3	47.4	47.6	47.8	48.0	48.1
49.5	47.2	47.4	47.6	47.8	47.9	48.1	48.3	48.5	48.6
50.0	47.7	47.9	48.1	48.3	48.4	48.6	48.8	49.0	49.1
50.5	48.2	48.4	48.6	48.8	48.9	49.1	49.3	49.5	49.6
51.0	48.7	48.9	49.1	49.3	49.4	49.6	49.8	50.0	50.1
51.5	49.2	49.4	49.6	49.8	49.9	50.1	50.3	50.5	50.6
52.0	49.7	49.9	50.1	50.3	50.4	50.6	50.8	51.0	51.1
52.5	50.2	50.4	50.6	50.8	50.9	51.1	51.3	51.5	51.6
53.0	50.7	50.9	51.1	51.3	51.4	51.6	51.8	52.0	52.1
53.5	51.2	51.4	51.6	51.8	51.9	52.1	52.3	52.5	52.6
54.0	51.7	51.9	52.1	52.3	52.4	52.6	52.8	53.0	53.1
54.5	52.2	52.4	52.6	52.8	52.9	53.1	53.3	53.5	53.6
55.0	52.7	52.9	53.1	53.3	53.4	53.6	53.8	54.0	54.1

Barometer Reading, mm—Continued

740	745	750	755	760	765	770	775	780	785
				Flash point, °C.					
18.3	18.5	18.7	18.8	**19.0**	19.2	19.4	19.5	19.7	19.9
18.8	19.0	19.2	19.3	**19.5**	19.7	19.9	20.0	20.2	20.4
19.3	19.5	19.7	19.8	**20.0**	20.2	20.4	20.5	20.7	20.9
19.8	20.0	20.2	20.3	**20.5**	20.7	20.9	21.0	21.2	21.4
20.3	20.5	20.7	20.8	**21.0**	21.2	21.4	21.5	21.7	21.9
20.8	21.0	21.2	21.3	**21.5**	21.7	21.9	22.0	22.2	22.4
21.3	21.5	21.7	21.8	**22.0**	22.2	22.4	22.5	22.7	22.9
21.8	22.0	22.2	22.3	**22.5**	22.7	22.9	23.0	23.2	23.4
22.3	22.5	22.7	22.8	**23.0**	23.2	23.4	23.5	23.7	23.9
22.8	23.0	23.2	23.3	**23.5**	23.7	23.9	24.0	24.2	24.4
23.3	23.5	23.7	23.8	**24.0**	24.2	24.4	24.5	24.7	24.9
23.8	24.0	24.2	24.3	**24.5**	24.7	24.9	25.0	25.2	25.4
24.3	24.5	24.7	24.8	**25.0**	25.2	25.4	25.5	25.7	25.9
24.8	25.0	25.2	25.3	**25.5**	25.7	25.9	26.0	26.2	26.4
25.3	25.5	25.7	25.8	**26.0**	26.2	26.4	26.5	26.7	26.9
25.8	26.0	26.2	26.3	**26.5**	26.7	26.9	27.0	27.2	27.4
26.3	26.5	26.7	26.8	**27.0**	27.2	27.4	27.5	27.7	27.9
26.8	27.0	27.2	27.3	**27.5**	27.7	27.9	28.0	28.2	28.4
27.3	27.5	27.7	27.8	**28.0**	28.2	28.4	28.5	28.7	28.9
27.8	28.0	28.2	28.3	**28.5**	28.7	28.9	29.0	29.2	29.4
28.3	28.5	28.7	28.8	**29.0**	29.2	29.4	29.5	29.7	29.9
28.8	29.0	29.2	29.3	**29.5**	29.7	29.9	30.0	30.2	30.4
29.3	29.5	29.7	29.8	**30.0**	30.2	30.4	30.5	30.7	30 9
29.8	30.0	30.2	30.3	**30.5**	30.7	30.9	31.0	31.2	31.4
30.3	30.5	30.7	30.8	**31.0**	31.2	31.4	31.5	31.7	31.9
30.8	31.0	31.2	31.3	**31.5**	31.7	31.9	32.0	32.2	32.4
31.3	31.5	31.7	31.8	**32.0**	32.2	32.4	32.5	32.7	32.9
31.8	32.0	32.2	32.3	**32.5**	32.7	32.9	33.0	32.2	33.4
32.3	32.5	32.7	32.8	**33.0**	33.2	33.4	33.5	33.7	33.9
32.8	33.0	33.2	33.3	**33.5**	33.7	33.9	34.0	34.2	34.4
33.3	33.5	33.7	33.8	**34.0**	34.2	34.4	34.5	34.7	34.9
33.8	34.0	34.2	34.3	**34.5**	34.7	34.9	35.0	35.2	35.4
34.3	34.5	34.7	34.8	**35.0**	35.2	35.4	35.5	35.7	35.9
34.8	35.0	35.2	35.3	**35.5**	35.7	35.9	36.0	36.2	36.4
35.3	35.5	35.7	35.8	**36.0**	36.2	36.4	36.5	36.7	36.9
35.8	36.0	36.2	36.3	**36.5**	36.7	36.9	37.0	37.2	37.4
36.3	36.5	36.7	36.8	**37.0**	37.2	37.4	37.5	37.7	37.9

Barometer Reading, mm—Continued

740	745	750	755	760	765	770	775	780	785
				Flash Point, °C.					
36.8	37.0	37.2	37.3	**37.5**	37.7	37.9	38.0	38.2	38.4
37.3	37.5	37.7	37.8	**38.0**	38.2	38.4	38.5	38.7	38.9
37.8	38.0	38.2	38.3	**38.5**	38.7	38.9	39.0	39.2	39.4
38.3	38.5	38.7	38.8	**39.0**	39.2	39.4	39.5	39.7	39.9
38.8	39.0	39.2	39.3	**39.5**	39.7	39.9	40.0	40.2	40.4
39.3	39.5	39.7	39.8	**40.0**	40.2	40.4	40.5	40.7	40.9
39.8	40.0	40.2	40.3	**40.5**	40.7	40.9	41.0	41.2	41.4
40.3	40.5	40.7	40.8	**41.0**	41.2	41.4	41.5	41.7	41.9
40.8	41.0	41.2	41.3	**41.5**	41.7	41.9	42.0	42.2	42.4
41.3	41.5	41.7	41.8	**42.0**	42.2	42.4	42.5	42.7	42.9
41.8	42.0	42.2	42.3	**42.5**	42.7	42.9	43.0	43.2	43.4
42.3	42.5	42.7	42.8	**43.0**	43.2	43.4	43.5	43.7	43.9
42.8	43.0	43.2	43.3	**43.5**	43.7	43.9	44.0	44.2	44.4
43.3	43.5	43.7	43.8	**44.0**	44.2	44.4	44.5	44.7	44.9
43.8	44.0	44.2	44.3	**44.5**	44.7	44.9	45.0	45.2	45.4
44.3	44.5	44.7	44.8	**45.0**	45.2	45.4	45.5	45.7	45.9
44.8	45.0	45.2	45.3	**45.5**	45.7	45.9	46.0	46.2	46.4
45.3	45.5	45.7	45.8	**46.0**	46.2	46.4	46.5	46.7	46.9
45.8	46.0	46.2	46.3	**46.5**	46.7	46.9	47.0	47.2	47.4
46.3	46.5	46.7	46.8	**47.0**	47.2	47.4	47.5	47.7	47.9
46.8	47.0	47.2	47.3	**47.5**	47.7	47.9	48.0	48.2	48.4
47.3	47.5	47.7	47.8	**48.0**	48.2	48.4	48.5	48.7	48.9
47.8	48.0	48.2	48.3	**48.5**	48.7	48.9	49.0	49.2	49.4
48.3	48.5	48.7	48.8	**49.0**	49.2	49.4	49.5	49.7	49.9
48.8	49.0	49.2	49.3	**49.5**	49.7	49.9	50.0	50.2	50.4
49.3	49.5	49.7	49.8	**50.0**	50.2	50.4	50.5	50.7	50.9
49.8	50.0	50.2	50.3	**50.5**	59.7	50.9	51.0	51.2	51.4
50.3	50.5	50.7	50.8	**51.0**	51.2	51.4	51.5	51.7	51.9
50.8	51.0	51.2	51.3	**51.5**	51.7	51.9	52.0	52.2	52.4
51.3	51.5	51.7	51.8	**52.0**	52.2	52.4	52.5	52.7	52.9
51.8	52.0	52.2	52.3	**52.5**	52.7	52.9	53.0	53.2	53.4
52.3	52.5	52.7	52.8	**53.0**	53.2	53.4	53.5	53.7	53.9
52.8	53.0	53.2	53.3	**53.5**	53.7	53.9	54.0	54.2	54.4
53.3	53.5	53.7	53.8	**54.0**	54.2	54.4	54.5	54.7	54.9
53.8	54.0	54.2	54.3	**54.5**	54.7	54.9	55.0	55.2	55.4
54.3	54.5	54.7	54.8	**55.0**	55.2	55.4	55.5	55.7	55.9

Heat Units

Temperature ° Fahrenheit = 9/5° C. + 32°* = 9/4° R. + 32°.
Temperature ° Celcius or ° Centigrade = 5/9 (° F. — 32°)* = 5/4° R.
Temperature ° Reaumur = 4/9 ° C. = 4/9 (° F.— 32°).

A British Thermal Unit (B. t. u.) is the amount of heat required to raise the temperature of 1 lb. avoir. of water 1° F. 1 B. t. u. = .252 Kilogram Calorie.

A Gram Calorie (small) is the amount of heat required to raise the temperature of 1 g. of water 1° C.

A Kilogram Calorie (large) is the amount of heat required to raise the temperature of 1 kg. of water 1° C.

One Kilogram Calorie — 1000 Gram Caloric = 3.968 B. t. u.

Power Units

A foot-pound is the power or energy required to raise a weight of 1 lb. (avoir.) a distance of 1 ft.

One Horse Power (h. p.) = 550. ft.-lbs. per second.
= 1.014 Cheval.
= 0.7457 Kilowatts.

A Kilogram-meter is the power or energy required to raise a weight of 1 kg. a distance of 1 M.

One Cheval (metric horse power) = 75 kg.-m. per second.
= 0.9863 h. p.
= 0.7355 kilowatts.

Electrical Units

The Volt is the unit of electrical pressure or electromotive force (e.m.f.)
The Ampere is the unit of electrical current or flow.
The Ohm is the unit of electrical resistance.
From Ohm's Law

$$\text{Amperes} = \frac{\text{Volts}}{\text{Ohms}}$$

$$\text{Volts} = \text{Ohms} \times \text{Amperes.}$$

$$\text{Ohms} = \frac{\text{Volts}}{\text{Amperes}}$$

The Watt is the unit of electrical power and is produced by the flow of 1 ampere under an e.m.f. of 1 volt.

1 kilowatt = 1000 watts
= 1.341 h. p.
1 watt = 0.001341 h. p.
= 0.7376 ft.-lbs. per sec.
= 0.000239 kg.-calorie per sec.
= 0.0009486 B. t. u. per sec.

The Joule is the unit of electrical energy and is 1 watt-second or is produced by a steady current of 1 ampere passed through a resistance of 1 ohm for 1 second. 1 joule = 0.2388 gram-calorie.

Heat of Combustion

	Calories per Gram	B. T. U. per Pound
Alcohol, Ethyl	7184	12931
Benzol, Liquid	10030	18054
Carbon, Crystallized	7859	14146
Cellulose	4208	7574
Charcoal	8080	14544
Coal, Anthracite	7800–8400	14000–15200
Bituminous	7800–8750	14000–15750
Coke	7900–8040	14200–14500
Gas, Acetylene	11927	21469
Coal	4400–7370	7990–12266
Oil or Petroleum	10800	19440
Producer	773–1370	1391–2466
Water	2000–3000	4200–5400
Gasoline	11733	21120
Glycerine	4316	7769
Graphite	7901	14222
Hydrogen	34462	62032
Kerosene	11186	20135
Lignite	6000–7000	10800–12600
Magnesium	6077	10939
Napthalene	9690	17442
Oil, Cotton Seed	9500	17100
Fuel	10300–10700	18500–19300
Olive	9473	17051
Rape	9489	17081
Sperm	10000	18000
Paraffin	11140	20050
Peat	5940	10692
Petroleum, Liquid	10000–12000	18000–21600
Pitch	8400	15120
Starch	4228	7610
Sugar Cane,	3961	7130
Sulphur	2221	3998
Tallow	9500	17100
Wood, Hard	4750	8550
Soft resinous	5050	9090

1.8 × Calories per gram = B. T. Us. per pound.
0.555 × B. T. Us. per pound = Calories per gram.

Barometer Readings, Boiling Points and Altitudes

Barometer Reading Inches Mercury	Barometer Reading Millimeters Mercury	Boiling Point ° F.	Boiling Point ° C.	Altitude in Feet Approximate
30.52	775.2	213.0	100.6	— 550
30.40	772.2	212.8	100.4	— 450
30.28	769.1	212.6	100.3	— 340
30.16	766.1	212.4	100.2	— 230
30.04	763.0	212.2	100.1	— 120
29.92	760.0	212.0	100.0	0
29.80	756.9	211.8	99.9	100
29.68	753.9	211.6	99.8	210
29.57	751.1	211.4	99.7	310
29.45	748.0	211.2	99.6	420
29.33	745.0	211.0	99.5	530
29.21	741.9	210.8	99.3	650
29.10	739.1	210.6	99.2	750
28.98	736.1	210.4	99.1	860
28.87	733.3	210.2	99.0	970
28.75	730.3	210.0	98.9	1080
28.63	727.2	209.8	98.8	1190
28.52	724.4	209.6	98.7	1300
28.41	721.6	209.4	98.6	1400
28.29	718.6	209.2	98.5	1520
28.18	715.8	209.0	98.3	1620
28.07	713.0	208.8	98.2	1730
27.95	709.9	208.6	98.1	1850
27.84	707.1	208.4	98.0	1960
27.73	704.3	208.2	97.9	2060
27.62	701.6	208.0	97.8	2170
27.51	698.8	207.8	97.7	2280
27.39	695.7	207.6	97.6	2400
27.28	692.9	207.4	97.4	2510
27.17	690.1	207.2	97.3	2620
27.06	687.3	207.0	97.2	2730
26.96	684.8	206.8	97.1	2830
26.85	682.0	206.6	97.0	2940
26.74	679.2	206.4	96.9	3060
26.63	676.4	206.2	96.8	3170
26.52	673.6	206.0	96.7	3280
26.41	670.8	205.8	96.6	3400
26.31	668.3	205.6	96.4	3500
26.20	665.5	205.4	96.3	3610
26.09	662.7	205.2	96.2	3720
25.99	660.2	205.0	96.1	3830

Barometer Readings, Boiling Points and Altitudes—Continued

Barometer Reading Inches Mercury	Barometer Reading Millimeters Mercury	Boiling Point ° F.	Boiling Point ° C.	Altitude in Feet Approximate
25.88	657.4	204.8	96.0	3950
25.78	654.8	204.6	95.9	4050
25.67	652.0	204.4	95.8	4170
25.57	649.5	204.2	95.7	4270
25.46	646.7	204.0	95.6	4390
25.36	644.2	203.8	95.4	4500
25.26	641.6	203.6	95.3	4610
25.15	638.8	203.4	95.2	4730
25.05	636.3	203.2	95.1	4830
24.95	633.7	203.0	95.0	4950
24.85	631.2	202.8	94.9	5060
24.74	628.4	202.6	94.8	5180
24.64	625.9	202.4	94.7	5290
24.54	623.3	202.2	94.6	5400
24.44	620.8	202.0	94.4	5510
24.34	618.2	201.8	94.3	5630
24.24	615.7	201.6	94.2	5730
24.14	613.2	201.4	94.1	5850
24.04	610.6	201.2	94.0	5960
23.94	608.1	201.0	93.9	6070
23.84	605.5	200.8	93.8	6190
23.75	603.3	200.6	93.7	6290
23.65	600.7	200.4	93.6	6410
23.55	598.2	200.2	93.5	6530
23.45	595.6	200.0	93.4	6650
23.00	584.2	199.1	92.8	7170
22.50	571.5	198.0	92.2	7770
22.00	558.8	196.9	91.6	8390
21.50	546.1	195.8	91.0	9010
21.00	533.4	194.7	90.4	9660
20.50	520.7	193.6	89.8	10320
20.00	508.0	192.4	89.1	10990
19.50	495.3	191.2	88.4	11680
19.00	482.6	190.0	87.8	12390
18.50	469.9	188.8	87.1	13120
18.00	457.2	187.5	86.4	13870
17.50	444.5	186.2	85.7	14630
17.00	431.8	184.8	84.9	15430

Calculated from Smithsonian Meteorological Tables, 3d Revised Edition.

English Inches Into Millimeters

In.	0	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16
0	0.0	1.6	3.2	4.8	6.4	7.9	9.5	11.1	12.7	14.3	15.9	17.5	19.1	20.6	22.2	23.8
1	25.4	27.0	28.6	30.2	31.7	33.3	34.9	36.5	38.1	39.7	41.3	42.9	44.4	46.0	47.6	49.2
2	50.8	52.4	54.0	55.6	57.1	58.7	60.3	61.9	63.5	65.1	66.7	68.3	69.8	71.4	73.0	74.6
3	76.2	77.8	79.4	81.0	82.5	84.1	85.7	87.3	88.9	90.5	92.1	93.7	95.2	96.8	98.4	100.0
4	101.6	103.2	104.8	106.4	108.0	109.5	111.1	112.7	114.3	115.9	117.5	119.1	120.7	122.2	123.8	125.4
5	127.0	128.6	130.2	131.8	133.4	134.9	136.5	138.1	139.7	141.3	142.9	144.5	146.1	147.6	149.2	150.8
6	152.4	154.0	155.6	157.2	158.8	160.3	161.9	163.5	165.1	166.7	168.3	169.9	171.5	173.0	174.6	176.2
7	177.8	179.4	181.0	182.6	184.2	185.7	187.3	188.9	190.5	192.1	193.7	195.3	196.9	198.4	200.0	201.6
8	203.2	204.8	206.4	208.0	209.6	211.1	212.7	214.3	215.9	217.5	219.1	220.7	222.3	223.8	225.4	227.0
9	228.6	230.2	231.8	233.4	235.0	236.5	238.1	239.7	241.3	242.9	244.5	246.1	247.7	249.2	250.8	252.4
10	254.0	255.6	257.2	258.8	260.4	261.9	263.5	265.1	266.7	268.3	269.9	271.5	273.1	274.6	276.2	277.8
11	279.4	281.0	282.6	284.2	285.7	287.3	288.9	290.5	292.1	293.7	295.3	296.9	298.4	300.0	301.5	303.2
12	304.8	306.4	308.0	309.6	311.1	312.7	314.3	315.9	317.5	319.1	320.7	322.3	323.8	325.4	327.0	328.6
13	330.2	331.8	333.4	335.0	336.5	338.1	339.7	341.3	342.9	344.5	346.1	347.7	349.2	350.8	352.4	354.0
14	355.6	357.2	358.8	360.4	361.9	363.5	365.1	366.7	368.3	369.9	371.5	373.1	374.6	376.2	377.8	379.4
15	381.0	382.6	384.2	385.8	387.3	388.9	390.5	392.1	393.7	395.3	396.9	398.5	400.0	401.6	403.2	404.8
16	406.4	408.0	409.6	411.2	412.7	414.3	415.9	417.5	419.1	420.7	422.3	423.9	425.4	427.0	428.6	430.2
17	431.8	433.4	435.0	436.6	438.1	439.7	441.3	442.9	444.5	446.1	447.7	449.3	450.8	452.4	454.0	455.6
18	457.2	458.8	460.4	462.0	463.5	465.1	466.7	468.3	469.9	471.5	473.1	474.7	476.2	477.8	479.4	481.0
19	482.6	484.2	485.8	487.4	488.9	490.5	492.1	493.7	495.3	496.9	498.5	500.1	501.6	503.2	504.8	506.4
20	508.0	509.6	511.2	512.8	514.3	515.9	517.5	519.1	520.7	522.3	523.9	525.5	527.0	528.6	530.2	531.8
21	533.4	535.0	536.6	538.2	539.7	541.3	542.9	544.5	546.1	547.7	549.3	550.9	552.4	554.0	555.6	557.2
22	558 8	560 4	562.0	563.6	565.1	566.7	568.3	569.9	571.5	573.1	574.7	576.3	577.8	579.4	581.0	582.6
23	584.2	585.8	587.4	589.0	590.5	592.1	593.7	595.3	596.9	598.5	600.1	601.7	603.2	604.8	606.4	608.0

Equivalents of Decimal and Binary Fractions of an Inch in Millimeters

Fractions of an Inch	Millimeters	Decimals of an Inch	Fractions of an Inch	Millimeters	Decimals of an Inch
1/64	0.397	0.0156	33/64	13.097	0.5156
1/32	0.794	.0313	17/32	13.494	.5313
3/64	1.191	.0469	35/64	13.891	.5469
1/16	1.588	.0625	9/16	14.288	.5625
5/64	1.984	.0781	37/64	14.684	.5781
3/32	2.381	.0938	19/32	15.081	.5938
7/64	2.778	.1094	39/64	15.478	.6094
1/8	3.175	.1250	5/8	15.875	.6250
9/64	3.572	.1406	41/64	16.272	.6406
5/32	3.969	.1563	21/32	16.669	.6563
11/64	4.366	.1719	43/64	17.066	.6719
3/16	4.763	.1875	11/16	17.463	.6875
13/64	5.159	.2031	45/64	17.859	.7031
7/32	5.556	.2188	23/32	18.256	.7186
15/64	5.953	.2344	47/64	18.653	.7344
1/4	6.350	.2500	3/4	19.050	.7500
17/64	6.747	.2656	49/64	19.447	.7656
9/32	7.144	.2813	25/32	19.34	.7813
19/64	7.541	.2969	51/64	20.241	.7969
5/16	7.938	.3125	13/16	20.638	.8125
21/64	8.334	.3281	53/64	21.034	.8281
11/32	8.731	.3438	27/32	21.431	.8438
23/64	9.128	.3594	55/64	21.828	.8594
3/8	9.525	.3750	7/8	22.225	.8750
25/64	9.922	.3906	57/64	22.622	.8906
13/32	10.319	.4063	29/32	23.019	.9063
27/64	10.716	.4219	59/64	23.416	.9219
7/16	11.113	.4375	15/16	23.813	.9375
29/64	11.509	.4531	61/64	24.209	.9531
15/32	11.906	.4688	31/32	24.606	.9688
31/64	12.303	.4844	63/64	25.003	.9844
1/2	12.700	.5000	1	25.400	1.0000

Standard Units of Measure and Weight

Unit of Length

A *Meter* (m.) is taken from the international prototype meter at the International Bureau of Weights and Measures; at figure 0° C = 39.37 inches = 3.280833 feet = 100 centimeters.

A *Foot* (ft.) = 0.3048006 meters = 30.48006 centimeters = 12 inches.

Unit of Capacity

A *Liter* (l.) is the volume occupied by the mass of 1 kilogram of pure water at 4° C. under barometric pressure of 760 mm. = 0.264178 U. S. gallons = 61.025 cubic inches = 1000.027 cubic centimeters = 1,000 milliliters.

A *Gallon* U. S. (gal.) = 231 cubic inches = 3.785332 liters = 8.32823 lbs. pure water in air at 60° F = 3.777623 kilograms pure water in air at 60° F = 0.8327 imperial gallons = 4 quarts.

An *Imperial Gallon* (English) = 277.274 cubic inches = 4.54346 liters = 1.20032 U. S. gallons = 9.996 lbs. pure water at 60° F.

Unit of Weight or Mass

A *Kilogram* (kg.) is taken from the international prototype kilogram at the International Bureau of Weights and Measures = 2.204622341 lbs. avoirdupois = 2.6792285 lbs. troy = 15,432.356 grains = 1,000 grams.

A *Pound* (Avoirdupois) (lb.) = 0.4535924277 kg. = 453.5924277 grams = 1.2152778 lbs. troy = 16 oz. avoir. = 7000 grains.

Comparison of Metric and Customary Units

1. Length						2. Area					
Inches (in.)		Milli-meters (mm.)	Feet (ft.)		Meters (m.)	Square inches (sq. in.)		Square centim's ($cm.^2$)	Square feet (sq. ft.)		Square meters ($m.^2$)
0.039 37	= 1	1 = 0.304 801	0.155 00	= 1	1 = 0.092 90						
0.078 74	= 2	2 = 0.609 601	0.310 00	= 2	2 = 0.185 81						
0.118 11	= 3	3 = 0.914 402	0.465 00	= 3	3 = 0.278 71						
0.157 48	= 4	4 = 1.219 202	0.620 00	= 4	4 = 0.371 61						
0.196 85	= 5	5 = 1.524 003	0.775 00	= 5	5 = 0.464 52						
0.236 22	= 6	6 = 1.828 804	0.930 00	= 6	6 = 0.557 42						
0.275 59	= 7	7 = 2.133 604	1.085 00	= 7	7 = 0.650 32						
0.314 96	= 8	8 = 2.438 405	1.240 00	= 8	8 = 0.743 23						
0.354 33	= 9	9 = 2.743 205	1.395 00	= 9	9 = 0.836 13						
1	= 25.4001	3.280 83 = 1	1	= 6.452	10.764 = 1						
2	= 50.8001	6.561 67 = 2	2	= 12.903	21.528 = 2						
3	= 76.2002	9.842 50 = 3	3	= 19.355	32.292 = 3						
4	= 101.6002	13.123 33 = 4	4	= 25.807	43.055 = 4						
5	= 127.0003	16.404 17 = 5	5	= 32.258	53.819 = 5						
6	= 152.4003	19.685 00 = 6	6	= 38.710	64.583 = 6						
7	= 177.8004	22.965 83 = 7	7	= 45.161	75.347 = 7						
8	= 203.2004	26.246 67 = 8	8	= 51.613	86.111 = 8						
9	= 228.6005	29.527 50 = 9	9	= 58.065	96.875 = 9						

*Bureau of Standards Circular No. 47.

Comparison of Metric and Customary Units—Continued

3. Volume

Cubic inches* (cu. in.)		Cubic centimeters ($cm.^3$)	Cubic feet (cu. ft.)		Cubic meters ($m.^3$)	Cubic feet (cu. ft.)		Liters* (l.)
0.061 02	=	1	1	=	0.028 317	1	=	28.316
0.122 05	=	2	2	=	0.056 634	2	=	56.633
0.183 07	=	3	3	=	0.084 951	3	=	84.949
0.244 09	=	4	4	=	0.113 268	4	=	113.265
0.305 12	=	5	5	=	0.141 585	5	=	141.581
0.366 14	=	6	6	=	0.169 902	6	=	169.898
0.427 16	=	7	7	=	0.198 219	7	=	198.214
0.488 19	=	8	8	=	0.226 536	8	=	226.530
0.549 21	=	9	9	=	0.254 853	9	=	254.846
1	=	16.3872	35.214	=	1	0.035 315	=	1
2	=	32.7743	70.629	=	2	0.070 631	=	2
3	=	49.1615	105.943	=	3	0.105 946	=	3
4	=	65.5486	141.258	=	4	0.141 262	=	4
5	=	81.9358	176.572	=	5	0.176 577	=	5
6	=	98.3230	211.887	=	6	0.211 892	=	6
7	=	114.7101	247.201	=	7	0.247 208	=	7
8	=	131.0973	282.516	=	8	0.282 523	=	8
9	=	147.4845	317.830	=	9	0.317 839	=	9

*Cubic Inches to Liters divide comparative values in cubic centimeters by 1000. Liters to Cubic Inches multiply by 1000. Ex .1 Liter = 61.02 cu. in. and 1 cu. in. = 0.016387 l.

Comparison of Metric and Customary Units—Continued

4. Capacity—Liquid Measure

U. S. fluid ounces (fl. oz.)		Milliliters (ml.) or (cc.) *	U. S. gallons (gal.)		Liters (l.)
0.033 815	=	1	0.264 18	=	1
0.067 629	=	2	0.528 36	=	2
0.101 444	=	3	0.792 53	=	3
0.135 259	=	4	1.056 71	=	4
0.169 074	=	5	1.320 89	=	5
0.202 888	=	6	1.585 07	=	6
0.236 703	=	7	1.849 24	=	7
0.270 518	=	8	2.113 42	=	8
0.304 333	=	9	2.377 60	=	9
1	=	29.573	1	=	3.785 33
2	=	59.146	2	=	7.570 66
3	=	88.719	3	=	11.356 00
4	=	118.292	4	=	15.141 33
5	=	147.865	5	=	18.926 66
6	=	177.437	6	=	22.711 99
7	=	207.010	7	=	26.497 33
8	=	236.583	8	=	30.282 66
9	=	266.156	9	=	34.067 99

*1 cc. is commercially considered to equal 1 ml. Actually 1 ml. equals 1.000027 cc.

Comparison of Metric and Customary Units—Continued

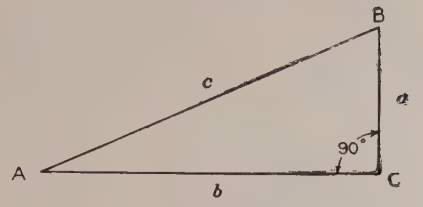
5. Mass or Weight

Grains (gr.)		Grams (g.)	Avoirdupois ounces (oz. av.)		Grams (g.)	Avoirdupois pounds (lb. av.)		Kilograms (kg.)
1	=	0.064 799	0.035 274	=	1	1	=	0.453 59
2	=	0.129 598	0.070 548	=	2	2	=	0.907 18
3	=	0.194 397	0.105 822	=	3	3	=	1.360 78
4	=	0.259 196	0.141 096	=	4	4	=	1.814 37
5	=	0.323 995	0.176 370	=	5	5	=	2.267 96
6	=	0.388 794	0.211 644	=	6	6	=	2.721 55
7	=	0.453 592	0.246 918	=	7	7	=	3.175 15
8	=	0.518 391	0.282 192	=	8	8	=	3.628 74
9	=	0.583 190	0.317 466	=	9	9	=	4.082 33
15.4324	=	1	1	=	28.350	2.204 62	=	1
30.8647	=	2	2	=	56.699	4.409 24	=	2
46.2971	=	3	3	=	85.049	6.613 87	=	3
61.7294	=	4	4	=	113.398	8.818 49	=	4
77.1618	=	5	5	=	141.748	11.023 11	=	5
92.5941	=	6	6	=	170.097	13.227 73	=	6
108.0265	=	7	7	=	198.447	15.432 36	=	7
123.4589	=	8	8	=	226.796	17.636 98	=	8
138.8912	=	9	9	=	255.146	19.841 60	=	9

Natural Sines, Tangents, Cosines and Cotangents

Degrees	Sine	Tangent	Cotangent	Cosine	
0	0	0	8	1	90
1	.0175	.0175	57.2900	.9998	89
2	.0349	.0349	28.6363	.9994	88
3	.0523	.0524	19.0811	.9986	87
4	.0698	.0699	14.3007	.9976	86
5	.0872	.0875	11.4301	.9962	85
6	.1045	.1051	9.5144	.9945	84
7	.1219	.1228	8.1443	.9925	83
8	.1392	.1405	7.1154	.9903	82
9	.1564	.1584	6.3138	.9877	81
10	.1736	.1763	5.6713	.9848	80
11	.1902	.1944	5.1446	.9816	79
12	.2079	.2126	4.7046	.9781	78
13	.2250	.2309	4.3315	.9744	77
14	.2419	.2493	4.0108	.9703	76
15	.2588	.2679	3.7321	.9659	75
16	.2756	.2867	3.4874	.9613	74
17	.2924	.3057	3.2709	.9563	73
18	.3090	.3249	3.0777	.9511	72
19	.3256	.3443	2.9042	.9455	71
20	.3420	.3640	2.7475	.9397	70
21	.3584	.3839	2.6051	.9336	69
22	.3746	.4040	2.4751	.9272	68
23	.3907	.4245	2.3559	.9205	67
24	.4067	.4452	2.2460	.9135	66
25	.4226	.4663	2.1445	.9063	65
26	.4384	.4877	2.0503	.8988	64
27	.4540	.5095	1.9626	.8910	63
28	.4695	.5317	1.8807	.8829	62
29	.4848	.5543	1.8040	.8746	61
30	.5000	.5774	1.7321	.8660	60
31	.5150	.6009	1.6643	.8572	59
32	.5299	.6249	1.6003	.8480	58
33	.5446	.6494	1.5399	.8387	57
34	.5592	.6745	1.4826	.8290	56
35	.5736	.7002	1.4281	.8192	55
36	.5878	.7265	1.3764	.8090	54
37	.6018	.7536	1.3270	.7986	53
38	.6157	.7813	1.2799	.7880	52
39	.6293	.8098	1.2349	.7771	51
40	.6428	.8391	1.1918	.7660	50
41	.6561	.8693	1.1504	.7547	49
42	.6691	.9004	1.1106	.7431	48
43	.6820	.9325	1.0724	.7314	47
44	.6947	.9657	1.0355	.7193	46
45	.7071	1.0000	1.0000	.7071	45
	Cosine	Cotangent	Tangent	Sine	Degrees

Solution of Right Triangles



1. Given an angle A and the adjacent side c.

$$a = c \sin. A$$
$$b = c \cos. A$$
$$B = 90° - A$$

---

2. Given an angle A and the opposite side a.

$$c = \frac{a}{\sin. A}$$
$$b = c \cos. A$$
$$B = 90° - A$$

---

3. Given an angle A and the base b.

$$c = \frac{b}{\cos. A}$$
$$a = c \sin. A$$
$$B = 90° - A$$

---

4. Given the two adjacent sides a and c.

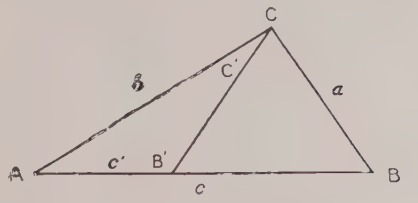
$$\sin. A = \frac{a}{c}$$
$$B = 90° - A$$
$$b = c \cos. A$$

---

5. Given one side a and the base b.

$$\tan. A = \frac{a}{b}$$
$$B = 90° - A$$
$$c = \frac{a}{\sin. A}$$

Solution of Oblique Triangles



1. Given two angles A and B and one side a.

$$C = 180° - (A + B)$$
$$b = \frac{a \sin. B}{\sin. A}$$
$$c = \frac{a \sin. C}{\sin. A}$$

2. Given two sides a and b and one opposite angle A. If A is less than 90° and value of a is between b and b sin. A there are two possible solutions.

First $\triangle$ A B C

$$\sin. B = \frac{b \sin. A}{a}$$
$$C = 180° - (A + B)$$
$$c = \frac{a \sin. C}{\sin. A}$$

Second $\triangle$ A B′ C′

$$B' = 180° - B$$
$$C' = 180° - (A + B')$$
$$c' = \frac{a \sin. C'}{\sin. A}$$

If A is less than 90° and value of a is less than b sin. A, or if A is greater than 90° and value of a is equal to or less than b, there is no solution. In all other cases there is one solution.

$$\sin. B = \frac{b \sin. A}{a}$$
$$C = 180° - (A + B)$$
$$c = \frac{a \sin. C}{\sin. A}$$

Solution of Oblique Triangles—Continued

3. Given two sides b and c and the included angle A if A is less than 90°.

$$a^2 = b^2 + c^2 - 2\,b\,c \cos. A$$

$$\sin. B = \frac{b \sin. A}{a}$$

$$\sin. C = \frac{c \sin. A}{a}$$

---

4. Given two sides a and b and the included angle C, if C is greater than 90°.

$$\tfrac{1}{2}(A + B) = \tfrac{1}{2}(180° - C)$$

$$\tan. \tfrac{1}{2}(A - B) = \frac{a - b}{a + b} \tan. \tfrac{1}{2}(A + B)$$

$$A = \tfrac{1}{2}(A + B) + \tfrac{1}{2}(A - B),$$

$$B = \tfrac{1}{2}(A + B) - \tfrac{1}{2}(A - B)$$

$$c = \frac{a \sin. C}{\sin. A}$$

---

5. Given the three sides a, b and c.

$$S = \tfrac{1}{2}(a + b + c)$$

$$\Upsilon = \sqrt{\frac{(s - a)\,(s - b)\,(s - c)}{s}}$$

$$\tan. \tfrac{1}{2} A = \frac{r}{s - a}$$

$$\tan \tfrac{1}{2} B = \frac{r}{s - b}$$

$$\tan. \tfrac{1}{2} C = \frac{r}{s - c}$$

If only one angle is required as A.

$$\cos. \tfrac{1}{2} A = \sqrt{\frac{s\,(s - a)}{bc}}$$

Lines, Areas and Volumes

Circumference of a circle = diameter × 3.1416.
= radius × 6.2832.

Radius of a circle = circumference × .159155.

Diameter of a circle = circumference × .31831.

Side of an inscribed equilateral triangle = diameter of circle × .86.

Side of an inscribed square = diameter of circle × .7071.
= circumference of circle × .225.

Side of an inscribed cube = radius of sphere × 1.1547.

Area of a circle = radius² × 3.1416.
= diameter² × .7854.
= circumference² × .07958.

Area of a square = a side².

Area of a triangle = base × ½ altitude.

Area of a rectangle = base × altitude.

Area of a parallelogram = base × altitude.

Area of a trapezoid = altitude × ½ sum of parallel sides.

Area of a parabola = ⅔ base × altitude of exterior triangle.

Area of a trapezium = area of the two constituent triangles.

Area of a regular polygon = ½ the perpendicular from the center to one of the sides × sum of the sides.

Area of a sector = ½ radius × arc.

Area of an ellipse = ½ short diameter × ½ long diameter × 3.1416.

Surface of a sphere = circumference × diameter.
= diameter² × 3.1416.

Surface of a cube = area of one side × 6.

Surface of a cylinder = area of both ends + (length × circumference).

Surface of a zone or convex surface of segment of a sphere = 6.2832 × radius of sphere from which it is cut × altitude of the zone.

Surface of a frustrum of a cone = ½ (sum of circumferences at both ends) × slant height + area of both ends.

Volume of a sphere = surface × ⅙ diameter.
= diameter³ × .5236.

Volume of a cube = one side³.

Volume of a cylinder or prism = area of end × length.

Volume of a cone or pyramid = area of base × ⅓ altitude.

Volume of a frustrum of a cone or pyramid = ⅓ altitude × area of both ends + square root of area of both ends multiplied together.

Volume of a wedge = area of base × ½ altitude.

Volume of a spherical segment of one base = ½ altitude × 3.1416 × radius of base² + ⅙ altitude³ × 3.1416.

Comparison of Gauges

Gauge or Number	American or Brown & Sharpe's	Birmingham or Stubs	Wash. & Moen.	United States Standard	Stub's Steel Wire	Morse Twist Dril	Shee Zinc	Sheet Copper
0000000			.4900	.5000				See note
000000	.5800		.4600	.4688				below
00000	.5165		.4300	.4375				
0000	.4600	.454	.3938	.4063				
000	.4096	.425	.3625	.3750				
00	.3648	.380	.3310	.3438				
0	.3249	.340	.3065	.3125				
1	.2893	.300	.2830	.2813	.227	.2280		
2	.2576	.284	.2625	.2656	.219	.2210		0027
3	.2294	.259	.2437	.2500	.212	.2130		
4	.2043	.238	.2253	.2344	.207	.2090	.008	.0054
5	.1819	.220	.2070	.2188	.204	.2055	.010	
6	.1620	.203	.1920	.2031	.201	.2040	.012	.0081
7	.1443	.180	.1770	.1875	.199	.2010	.014	
8	.1285	.165	.1620	.1719	.197	.1990	.016	.0108
9	.1144	.148	.1483	.1563	.194	.1960	.018	
10	.1019	.134	.1350	.1406	.191	.1935	.020	.0135
11	.0907	.120	.1205	.1250	.188	.1910	.024	
12	.0808	.109	.1055	.1094	.185	.1890	.028	.0162
13	.0720	.095	.0915	.0938	.182	.1850	.032	
14	.0641	.083	.0800	.0781	.180	.1820	.036	.0189
15	.0571	.072	.0720	.0703	.178	.1800	.040	
16	.0508	.065	.0625	.0625	.175	.1770	.045	0216
17	.0453	.058	.0540	.0563	.172	.1730	.050	
18	.0403	.049	.0475	.0500	.168	.1695	.055	.0243
19	.0359	.042	.0410	.0438	.164	.1660	.060	
20	.0320	.035	.0348	.0375	.161	.1610	.070	.0270
21	.0285	.032	.0318	.0344	.157	.1590	.080	
22	.0254	.028	.0286	.0313	.155	.1570	.090	
23	.0226	.025	.0258	.0281	.153	.1540		
24	.0201	.022	.0230	.0250	.151	.1520		.0324
25	.0179	.020	.0204	.0219	.148	.1495		
26	.0159	.018	.0181	.0188	.146	.1470		
27	.0142	.016	.0173	.0172	.143	.1440		
28	.0126	.014	.0162	.0156	.139	.1405		.0378
29	.0113	.013	.0150	.0141	.134	.1360		
30	.0100	.012	.0140	.0125	.127	.1285		
31	.0089	.010	.0132	.0109	.120	.1200		
32	.0080	.009	.0128	.0102	.115	.1160		.0432
33	.0071	.008	.0118	.0094	.112	.1130		
34	.0063	.007	.0104	.0086	.110	.1110		
35	.0056	.005	.0095	.0078	.108	1100		

Comparison of Gauges—Continued

Gauge or Number	American or Brown & Sharpe's	Birmingham or Stubs	Wash. & Moen.	United States Standard	Stub's Steel Wire	Morse Twist Drill	Sheet Zinc	Sheet Copper
36	.0050	.004	.0090	.0070	.106	.1065		.0486
37	.0045		.0085	.0066	.103	.1040		
38	.0040		.0080	.0063	.101	.1015		
39	.0035		.0075		.099	.0995		
40	.0031		.0070		.097	.0980		.0540
41	.0028				.095	.0960		
42	.0025				.092	.0935		
43	.0022				.088	.0890		
44	.0020				.085	.0860		.0594
45	.0018				.081	.0820		
46	.0016				.079	.0810		
47	.0014				.077	.0785		
48	.0012				.075	.0760		0648
49	.0010+				.072	.0730		
50	.0010—				.069	.0700		
51					.066	.0670		
52					.063	.0635		
53					.058	.0595		
54					.055	.0550		
55					.050	.0520		
56					.045	.0465		0756
57					.042	.0430		
58					.041	.0420		
59					.040	.0410		
60					.039	.0400		
61					.038			
62					037			
63					.036			
64					.035			0864
65					.033			
66					.032			
67					.031			
68					.030			
69					.029			
70					.027			
71					.026			
72					.024			.0972
73					.023			
74					.022			
75					.020			
76					.018			
77					.016			
78					.015			
79					.014			
80					.013			.1080

NOTE: For sheet copper table numbers in left hand column give oz. per square foot.

Correction to Distillation Temperatures for Barometric Pressure*

The actual barometer pressure should be ascertained and recorded when making a distillation test.

No correction is necessary except in case of a dispute, when the temperature points should be corrected to a standard of 760 mm (29.92 in.) by use of the Sidney Young equation, as follows:

For Centigrade readings: $X=0.00012\ (760-P)\ (273+°C.)$

For Fahrenheit readings: $X=0.00012\ (760-P)\ (460+°F.)$

In which X=Correction to be added when actual barometer pressure is below 760 mm; subtracted when barometric pressure is above 760 mm.

P=actual barometric pressure in millimeters of mercury.

The following table is a convenient approximation of the corrections as calculated by the above equation.

Temperature range		Correction per 10mm difference in Pressure	
°C	°F	°C	°F
10- 30	50- 86	0.35	0.63
30- 50	86-112	0.38	0.68
50- 70	112-158	0.40	0.72
70- 90	158-194	0.42	0.76
90-110	194-230	0.45	0.81
110-130	230-266	0.47	0.85
130-150	266-302	0.50	0.89
150-170	302-338	0.52	0.94
170-190	338-374	0.54	0.98
190-210	374-410	0.57	1.02
210-230	410-446	0.59	1.06
230-250	446-482	0.62	1.11
250-270	482-518	0.64	1.15
270-290	518-554	0.66	1.19
290-310	554-590	0.69	1.24
310-330	590-626	0.71	1.28
330-350	626-662	0.74	1.32
350-370	662-698	0.76	1.37
370-390	698-734	0.78	1.41
390-410	734-770	0.81	1.45

* From A. S. T. M. Standards D 86-27 and D 216-27.

International Atomic Weights; 1925 Values

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Name of Element	Symbol	Atomic Weight	Name of Element	Symbol	Atomic Weight
Aluminum	Al	26.97	Molybdenum	Mo	96.0
Antimony	Sb	121.77	Neodymium	Nd	144.27
Argon	A	39.91	Neon	Ne	20.2
Arsenic	As	74.96	Nickel	Ni	58.69
Barium	Ba	137.37	Nitrogen	N	14.008
Beryllium	Be	9.02	Osmium	Os	190.18
Bismuth	Bi	209.0	Oxygen	O	16.000
Boron	B	10.82	Palladium	Pd	106.7
Bromine	Br	79.916	Phosphorus	P	31.027
Cadmium	Cd	112.41	Platinum	Pt	195.23
Caesium	Cs	132.81	Potassium	K	39.096
Calcium	Ca	40.07	Praseodymium	Pr	140.92
Carbon	C	12.000	Radium	Ra	225.95
Cerium	Ce	140.25	Radon	Rn	222.0
Cesium	Cs	132.81	Rhodium	Rh	102.91
Chlorine	Cl	35.457	Rubidium	Rb	85.44
Chromium	Cr	52.01	Ruthenium	Ru	101.7
Cobalt	Co	58.94	Samarium	Sa	150.43
Columbium	Cb	93.1	Scandium	Sc	44.10
Copper	Cu	63.57	Selenium	Se	79.2
Dysprosium	Dy	162.52	Silicon	Si	28.06
Erbium	Er	167.7	Silver	Ag	107.880
Europium	Eu	152.0	Sodium	Na	22.997
Fluorine	F	19.0	Strontium	Sr	87.63
Gadolinium	Gd	157.26	Sulfur	S	32.064
Gallium	Ga	69.72	Tantalum	Ta	181.5
Germanium	Ge	72.60	Tellurium	Te	127.5
Gold	Au	197.2	Terbium	Tb	159.2
Helium	He	4.0	Thallium	Tl	204.39
Holmium	Ho	163.4	Thorium	Th	232.15
Hydrogen	H	1.008	Thulium	Tm	169.4
Indium	In	114.8	Tin	Sn	118.70
Iodine	I	126.932	Titanium	Ti	48.1
Iridium	Ir	193.1	Tungsten	W	184.0
Iron	Fe	55.84	Uranium	U	238.17
Krypton	Kr	82.9	Vanadium	V	50.96
Lanthanum	La	138.90	Xenon	Xe	130.2
Lead	Pb	207.20	Ytterbium	Yb	173.6
Lithium	Li	6.940	Yttrium	Y	88.9
Lutecium	Lu	175.0	Zinc	Zn	65.38
Magnesium	Mg	24.32	Zirconium	Zr	91.0
Manganese	Mn	54.93			
Mercury	Hg	200.61			

* The Journal of the American Chemical Society, Vol. 47, 597 (1925)

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